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DEFORMITY

Posterior Global Malalignment After Osteotomy for Sagittal Plane Deformity

It Happens and Here is Why

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Study Design. Multicenter, retrospective analysis of 183 consecutive patients undergoing lumbar osteotomy.

Objective. To evaluate cause and impact of posterior postoperative alignment.

Summary of Background Data. Sagittal malalignment in the setting of adult spinal deformity (ASD) has shown significant correlation with pain and disability. Surgical treatment often entails correction of deformity by pedicle subtraction osteotomies (PSO). Key radiographical spinopelvic objectives to reach improvement in clinical outcomes have been previously reported. Although anterior alignment is a cause of poor outcomes, the impact and cause of posterior spinal alignment by PSO has not been reported.

Methods. The patient inclusion criteria were age, more than 18 years, with a diagnosis of sagittal plane deformity (C7 plumbline offset >5 cm, a pelvic tilt >20°, or a lumbar lordosis to pelvic incidence mismatch of ≥10°) requiring a surgical procedure involving a lumbar posterior osteotomy and a long fusion. Patients were divided into 3 groups based on postoperative sagittal vertical axis (SVA): neutral alignment (0 < SVA < 50 mm), anterior alignment (SVA > 50 mm), and posterior alignment (SVA < 0 mm). All patients underwent pre- and postoperative full-length sagittal spine radiography. Differences between groups were evaluated using ANOVA and χ^2 analysis.

Results. Seventy-six patients were postoperatively classified in the anterior group: 59 in the neutral group and 48 in the posterior group. These groups were comparable preoperatively in terms of surgical status (revision *vs*. primary surgery) and regional alignment (lumbar lordosis and thoracic kyphosis). The patients with posterior alignment were younger and had a significantly lower pelvic incidence (53° *vs*. 62°), preoperative pelvic tilt (30 *vs*. 36°), SVA (94 *vs*. 185 mm) and cervical lordosis (16° *vs*. 25°) than patients in the anterior alignment group. No significant differences were found in terms surgical procedure. Patients in the posterior alignment group demonstrated a significantly greater change in SVA and pelvic tilt correction ($P < 0.05$) but with a lower gain in thoracic kyphosis (5 *vs*. 12°) and reduction of cervical lordosis (4° *vs*. 22°).

Conclusion. A significantly lower pelvic incidence and lack of restoration of thoracic kyphosis may lead to sagittal overcorrection with a posterior alignment. Although the clinical significance of posterior malalignment is still unclear, this study showed a compensatory loss of cervical lordosis in these patients. Particular attention must be paid to preoperative planning before sagittal realignment procedures. Further study will be necessary to evaluate long-term clinical outcomes of these patients.

Key words: adult spinal deformity, pedicle subtraction osteotomy, outcomes, overcorrection, surgery. **Spine 2013;38:E394–E401**

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Management of patients with adult spinal deformity (ASD) remains one of the most challenging issues in the field of spinal surgery due to the complexity and the diversity of structural pathologies and clinical presentations. With a growing prevalence, reported as high as 60% in patients older than 60 years,[1] ASD is emerging as a major health care issue of the 21st century, underlining the necessity of carefully analyzing outcomes related to therapeutic options. Results from recent studies[2,3] have demonstrated the superiority of surgery compared with conservative care regarding back and leg pain, leading to a generally favorable risk/benefit ratio for ASD surgery, even in older patients.[4]

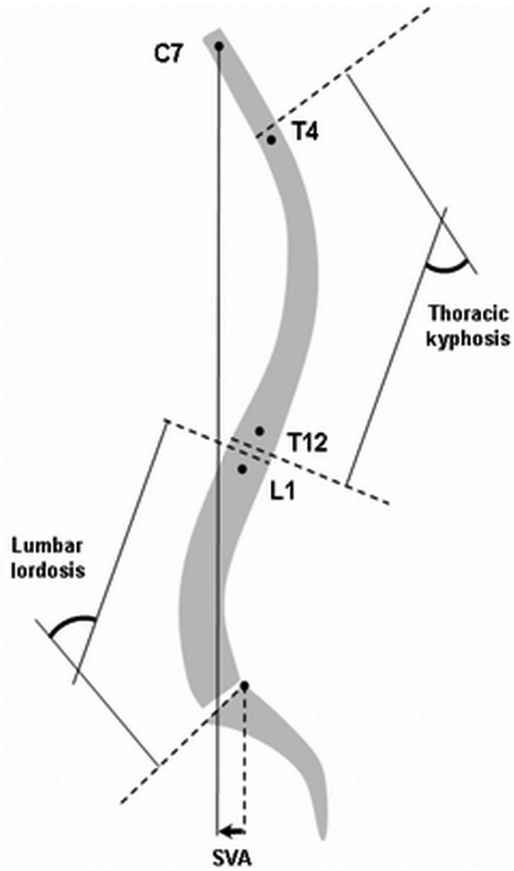

Figure 1. Sagittal spinal radiological parameters: thoracic kyphosis, lumbar lordosis, and sagittal vertical axis (SVA).

When surgery is planned in the setting of ASD, unlike for adolescent patients, pain and disability determine treatment modalities more than the deformity itself.[5] When surgical treatment is decided on the basis of the patient's clinical symptoms, surgical planning is highly influenced by the analysis of images (magnetic resonance imaging, computed tomography, and radiography). In this context, numerous studies have established that the analysis of sagittal alignment is critical. Key sagittal parameters to consider in the setting of ASD include regional spinal measures (thoracic kyphosis [TK], lumbar lordosis [LL], and cervical lordosis [CL]), global measures (sagittal vertical axis [SVA]) and pelvic measures (pelvic incidence [PI], pelvic tilt [PT], and sacral slope [SS]). These parameters have been shown to correlate with one another, creating a chain of correlation.[6,7]

Previous studies have reported the negative impact of anterior sagittal malalignment in patients with ASD, and the relationship between sagittal radiographical parameters and clinical outcomes, even if correlations were modest (Spearman $\rho < 0.3$).[8,9] These findings were confirmed with a higher correlation (Spearman ρ in the range of 0.29 to 0.55 for SVA) by Lafage *et al*[10] who also reported the necessity of including pelvic parameters in the sagittal plane assessment of patients. According to their study, among many parameters, T1 sagittal tilt, SVA, and PT were the most correlated with health related quality of life scores. More recently, Schwab *et al*[11] proposed thresholds of correction in the management of patients with ASD (SVA < 50 mm, PT < 20° and PI-LL < 10°), demonstrating that the difference between PI and LL was directly correlated to patient reported outcomes. These data are important for surgical management of patients with ASD and particularly for spinal realignment procedures.

In most cases of ASD with sagittal plane malalignment, the restoration of satisfactory alignment requires a complex procedure, frequently including a posterior long fusion and spinal osteotomies. Applying guidelines to correction thresholds is helpful for both preoperative planning[12] and postoperative evaluation of surgical correction. The increased recognition that good outcomes require alignment of the spinal column has lead to the broad use of complex osteotomies. The latter offer dramatic corrections of spinal deformity with a primary focus often being the concern of subomptimal correction. Numerous studies[13–15] have thus concentrated on identifying factors leading to under correction. However, because dramatic 3-column osteotomies are being popularized, there is a lack of knowledge related to patients with a postoperative posterior alignment (possible overcorrection). The objective of this study was thus to identify the occurrence and the intraoperative risk factors leading to postoperative posterior alignment in the management of sagittal plane deformity.

MATERIALS AND METHODS

Study Design and Inclusion Criteria

This study is based on a multicenter retrospective clinical and radiographical review of 183 consecutively patients with ASD from different sites across the United States. All subjects were enrolled according to an IRB protocol approved at each site. Inclusion criteria were patients older than 18 years with a diagnosis of sagittal plane deformity requiring a surgical procedure involving a posterior approach with a lumbar grade 3 osteotomy (*e.g.*, pedicle subtraction osteotomy, PSO) and

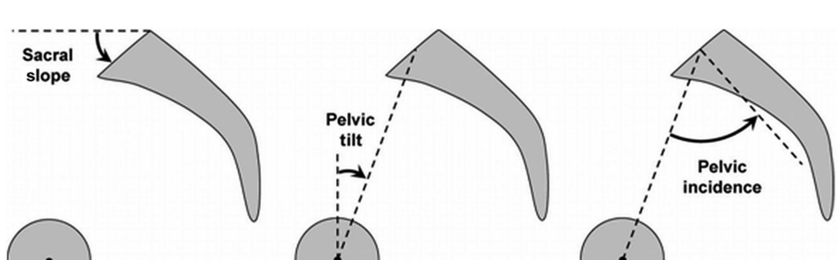

Figure 2. Pelvic parameters: sacral slope, pelvic incidence, and pelvic tilt.

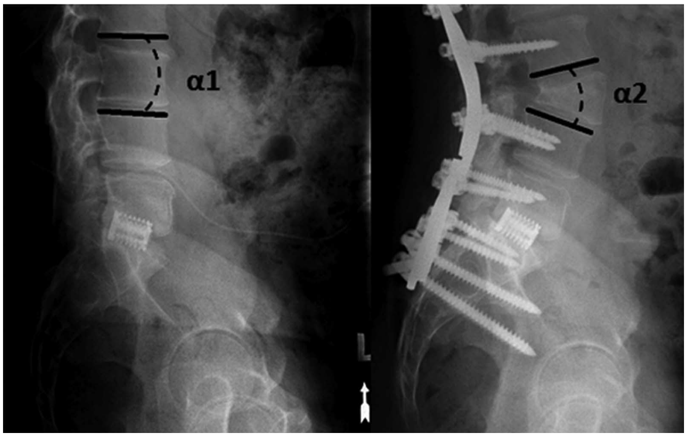

Figure 3. The osteotomy resection angle was defined as the change of the angle formed by the lower vertebral endplate of the adjacent cephalic vertebra and the upper vertebral endplate of the adjacent caudal vertebra.

a long fusion. Sagittal plane deformity criteria included any patient with a C7 plumbline offset (from S1) greater than 5 cm, a retroversion of the pelvis (*i.e.*, PT >20°) or a loss of LL (*i.e.*, PI-LL > 10°).[16] Patients with neuromuscular disease, trauma, spinal infections, ankylosing spondylitis, or tumors were not included in this study.

Data Collection and Radiographical Analysis

For each patient, full-length lateral spine radiographs (including femoral heads) in a free standing posture were obtained preoperatively and during the first 6 months after surgical procedure. Radiographs were analyzed to determine the upper instrumented vertebrae (UIV) and lower instrumented vertebrae (LIV), and radiographical measurements were performed using a dedicated and validated software[17,18] (Spineview, Paris, France). For this study, the analysis focused on the following sagittal spinopelvic parameters (Figures 1, 2):

- SVA is the linear offset from the C7 plumbline to the posterosuperior corner of S1.
- LL is the angle between the upper endplate of L1 and the superior endplate of S1.
- TK is the angle between the upper endplate of T4 and the inferior endplate of T12.
- PI is the angle between the line perpendicular to the sacral plate at its midpoint and the line connecting this point to the femoral rotational axis. PI is a morphological parameter.
- PT is the angle between the vertical and the line connecting the midpoint of the superior sacral endplate to the center of the femoral heads. PT is a positional parameter acting as one of the regulator of the standing posture; pelvic retroversion (*i.e.*, the posterior rotation of the pelvis) has been demonstrated to correlate with clinical outcomes in the setting of adult with spinal deformities.[10]
- SS is the angle between the horizontal and the superior endplate of S1. SS is also a positional parameter and completes to geometrical relationship among pelvic parameters, where PI = PT + SS.
- Osteotomy resection angle is the change in the angle formed by the lower vertebral endplate of the adjacent cephalic vertebra and the upper vertebral endplate of the adjacent caudal vertebra (Figure 3).

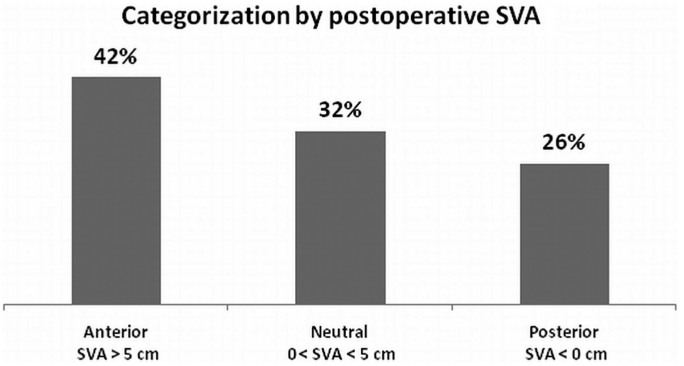

Figure 4. Group distribution based upon postoperative measurement of the sagittal vertical axis (sagittal vertical axis = horizontal offset from the C7 plumbline to the posterosuperior corner of S1).

Group Definition

On the basis of published correlations between SVA and patient reported clinical outcomes,[11] thresholds of postoperative SVA were used to subdivide the sample into 3 groups:

- Anterior global alignment group (anterior): patients with a postoperative SVA more than 5 cm.
- Neutral global alignment group (neutral): patients with a postoperative SVA between 0 and 5 cm.
- Posterior global alignment group (posterior): patients with a postoperative negative SVA.

Statistical Analysis

Mean group values were compared between patients with the neutral alignment, anterior alignment, and posterior alignment in terms of preoperative measurements, surgical parameters and postoperative measurements. Statistical analysis was performed using SPSS software (SPSS Inc, Chicago, IL). Changes between pre- and postoperative radiographical parameters were evaluated using a paired t test, group comparison was performed using ANOVA or χ^2 test, and correlations between radiographical parameters were evaluated using a Pearson coefficient. For all statistical analysis, the level of significance was set at 5% (*i.e.*, $P < 0.05$).

RESULTS

Demographic Data

A total of 183 patients with a mean age of 57 years (SD = 12 yr) were included in this study. Preoperatively the radiographical quantitative analysis of the sagittal plane revealed a mean SVA of 14.1 cm (SD = 7.8 cm), and mean PT of 32.4° (SD = 10.5°) and a mean LL of 19° (SD = 19°). The analysis of postoperative SVA (Figures 4, 5) demonstrated that 42%

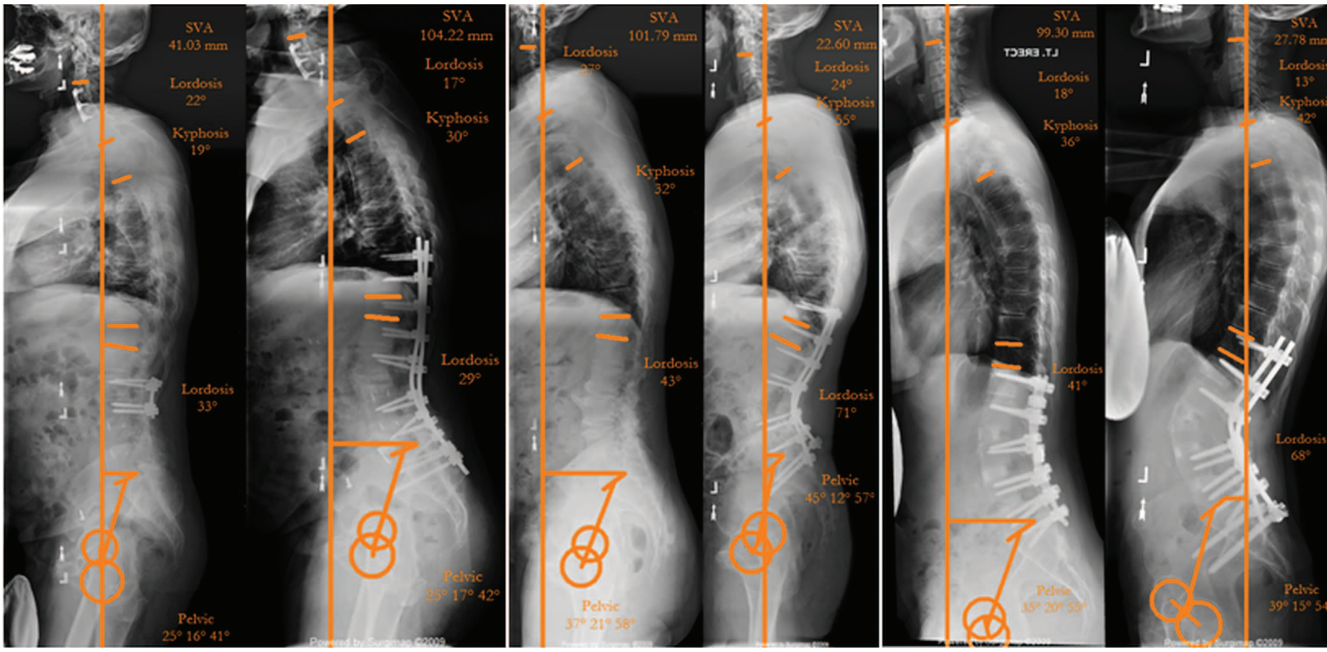

Figure 5. Example of pre- and postoperative radiographical analysis for patients in the anterior (left), neutral (center), and posterior (right) group. Overlay measures made with Surgimap Spine Software (Nemaris Inc. New York, NY). SVA indicates sagittal vertical axis.

(n = 76) of the patients fell into the anterior group (SVA > 5 cm), 32% (n = 59) in the neutral group, and 26% (n = 48) in the posterior group (SVA < 0 cm). Patients categorized into the posterior group (mean age, 51 yr, SD = 12, range 19–77) were significantly younger than the 2 other groups (mean age, 57 yr, SD = 12, range 24–77; and mean age, 60 yr, SD = 10, range, 36–81 for neutral and anterior group respectively, $P < 0.001$). Across the entire study population, only 13 patients were considered young adults (younger than 40 yr), 6 in the posterior group, 4 in the neutral group, and 3 in the anterior group, without significant differences in distribution between groups ($P > 0.05$).

The analysis of surgical history demonstrated that 66% of the patients were operated on in the setting of a revision surgery, without any significant differences between groups (70% in the anterior group, 61% in the neutral group and 66% in the posterior group, $P = 0.567$). Previous surgeries included mainly treatment of degenerative conditions such as disc herniation or lumbar stenosis, with or without instrumentation. However, none of the patients underwent a previous osteotomy prior to inclusion in the study.

Preoperative Radiographical Evaluation

The analysis of preoperative radiographical measurements demonstrated that patients from the 3 groups were not statistically different in terms of preoperative regional sagittal alignment (TK and LL) (Table 1). Interestingly, patients with neutral and posterior alignments were less likely to have abnormal spinopelvic measures preoperatively than the anteriorly aligned group. Compared with the anterior alignment group, the neutral and posterior alignment groups had

- a significantly lower PI ($P < 0.001$),
- a significantly lower PT ($P = 0.003$),
- a significantly lower preoperative SVA ($P < 0.001$),
- a significantly lower cervical lordosis [CL] ($P = 0.017$), and
- a lower PI-LL mismatch ($P < 0.001$).

Surgical Procedure

As outlined in Table 2, there were no significant differences between the posterior alignment group and the 2 others in terms of number of levels fused ($P = 0.368$), amount of osteotomy resection angle ($P = 0.376$), or level of osteotomy ($P = 0.204$) (Table 2). The most common PSO level was L3 for all groups; on average the upper instrumented vertebrae level was T6 for the posterior alignment group and T7 for the neutral and anterior alignment groups. In each group, most of the patients were fused to the pelvis.

Change in Radiographical Parameters

Comparison for each group between preoperative and postoperative values revealed significant changes for TK, LL, PT, SVA, and PI-LL mismatch ($P < 0.001$). Changes in cervical lordosis (CL) were significant for the posterior alignment group ($P < 0.001$) but not for the anterior and neutral alignment groups ($P = 0.079$ and $P = 0.079$).

The analysis of changes between preoperative and postoperative radiographical parameters demonstrated that patients classified into the posterior alignment group had a significantly greater change in SVA (11.8 cm +/−6 *vs.* 9.2 cm +/−6 for neutral and 8.2 cm +/− 8 for anterior; $P = 0.022$) and PT (12° +/−9 *vs.* 7° +/−7 for neutral and 7° +/−8 for anterior; $P = 0.012$). Additionally, the posterior alignment group also demonstrated a significantly smaller increase in TK than the other groups (5° +/−14 *vs.* 10° +/−17 for neutral and 11° +/−12 for anterior; $P = 0.038$). No significant difference in change of LL was visible between groups (30° +/−18 for

TABLE 1. Preoperative Radiographical Parameters (Mean ± Standard Deviation)

	Anterior (76 Patients)		Neutral (59 Patients)		Posterior (48 Patients)		P	Significance
CL (°)	25.3*	±16	17	±18	16.2	±17	0.017	Anterior > neutral and posterior
TK (°)	28.6	±20	30.9	±20	27.6	±18	0.696	NS
LL (°)	17.6	±20	26.3	±19	23.2	±17	0.098	NS
PI (°)	62*	±11	55	±12	52	±13	<0.001	Anterior > neutral and posterior
PT (°)	36*	±10	30	±9	30	±11	0.003	Anterior > neutral and posterior
SVA (mm)	185*	±73	123	±63	94	±62	<0.001	Anterior > neutral and posterior
PI-LL (°)	44*	±19	29	±18	30	±18	<0.001	Anterior > neutral and posterior

Significant differences between groups based on an ANOVA test between groups.

NS indicates nonsignificant; CL, cervical lordosis; LL, lumbar lordosis; TK, thoracic kyphosis; PI, pelvic incidence; PT, pelvic tilt; ANOVA analysis of variance.

posterior *vs*. 27° +/−18 for neutral and 27° +/−17 for anterior; $P = 0.561$). No significant differences in terms of change in parameters were found when comparing the anterior alignment group and the neutral one.

Postoperative Radiographical Evaluation

The analysis of postoperative sagittal radiographs between groups demonstrated that the anterior alignment group had a significantly lower LL than the 2 other groups ($P = 0.002$), while the posterior alignment had a significantly lower TK than the 2 other groups ($P = 0.014$) (Table 1). The posterior alignment group also had a significantly smaller postoperative C2–C7 lordosis (with a negative SVA, as defined by the inclusion criteria) than the 2 others groups ($P < 0.001$).

However, in addition to the differences in postoperative SVA (as per the inclusion criteria), the posterior alignment group also demonstrated a smaller postoperative PT (*Note*: none of these patients had a negative postoperative PT) as well as a smaller PI-LL mismatch than the than the 2 other groups ($P < 0.001$ and $P < 0.001$, respectively).

Analysis of the Compensatory Mechanisms

As expected, the analysis of preoperative alignment revealed that patients with anterior sagittal malalignment (*i.e.*, large SVA) had a flat LL (on average the LL was 30°–44° less than the PI). To compensate for this deformity, those patients also had an increased PT (*i.e.*, pelvic retroversion) in an effort to maintain the position of the head over the pelvis and an increase in CL in order to maintain a horizontal gaze. For the patients with postoperative anterior alignment, the surgery was not able to correct SVA and PT in an efficient way because there was still a mismatch between PI and LL, and the patients retained the compensatory mechanisms of elevated PT and a raised CL. For patients with posterior alignment, the PT and PI-LL mismatch were restored, but surgery lead to an overcorrected SVA, with a lack of restoration of TK. As a compensatory mechanism, these patients tended to have a kyphotic cervical spine in order to maintain horizontal gaze.

DISCUSSION

Adult spinal deformity covers a wide range of clinical presentations, and its treatment remains challenging and without strong consensus. Although surgical management is determined mainly on the basis of patient symptoms, previous studies have reported the critical impact of the restoration of normal sagittal alignment to improve clinical outcomes and prevent further decompensation.[10,13,14,19,20] Using

TABLE 2. Surgical Parameters Among the 3 Alignment Groups, No Significant Differences (NS) Were Found Between the Groups Based on ANOVA Test

	Anterior Alignment	Neutral Alignment	Posterior Alignment	Significance
PSO resection	21.5° SD = 9	22.3° SD = 11	24° SD = 13	0.376; NS
Number of levels fused	11	11	12	0.368; NS
UIV	T7	T7	T6	0.375; NS
LIV	Pelvis	Pelvis	Pelvis	0.601; NS
PSO level	L3	L3	L3	0.204; NS

ANOVA indicates analysis of variance; PSO, pedicle subtraction osteotomy; UIV, upper instrumented vertebrae, LIV lower instrumented vertebrae; SD, standard deviation.

TABLE 3. Postoperative Radiographical Parameters (Mean ± Standard Deviation)

	Anterior		Neutral		Posterior		P	Significance
CL (°)	22	±16	15	±14	4.3*	±17	<0.001	Posterior < anterior and neutral
TK (°)	41	±17	41	±16	33*	±14	0.014	Posterior < anterior and neutral
LL (°)	46*	±14	52	±13	53	±15	0.002	Anterior < posterior and neutral
PT (°)	28	±9	23	±9	18*	±8	<0.001	Anterior > neutral > posterior
SVA (mm)	98	±38	30	±12	−24*	±24	<0.001	Anterior > neutral > posterior
PI-LL (°)	16	±14	2	±13	−1*	±11	<0.001	Anterior > neutral > posterior

**Significant differences between groups based on ANOVA test.*

CL indictaes cervical lordosis; LL, lumbar lordosis; TK, thoracic kyphosis; PI, pelvic incidence; PT, pelvic tilt; SVA, sagittal vertical axis; ANOVA analysis of variance.

outcomes-related, and statistical, models, some authors have even proposed formulas to achieve a satisfactory postoperative alignment[21–23] and thresholds for optimal correction have been described by Schwab *et al*[11] with SVA less than 50 mm, PT less than 25°, and PI-LL less than 10°.

Causes of failure associated with sagittal realignment procedures are well known and can lead to poor clinical outcomes. The latter can be related to various factors, but it is now established that evaluation of SVA alone is not sufficient when addressing sagittal plane deformities. In recent work, Lafage *et al*[12] studied the impact of PSO level with respect to spinopelvic parameter correction. According to their results, PSO level (thoracic or lumbar) did not directly correlate with the degree of SVA correction, but more caudal PSOs were associated with a greater PT correction, while amount of osteotomy resection angle was correlated with change in TK, LL, PT, and SS. Progressive loss of deformity correction can also be related to an increased TK in patients with preoperative sagittal imbalance and short (lumbar) fusions.[24] This phenomenon has been described as unfavorable reciprocal changes[25] and is more frequent in older patients with a larger PI, for whom restoration of LL was inadequate to address the suboptimal PI-LL relationship.

The causes for posterior global alignment (negative SVA values) after realignment procedures are not well understood, and, to our best knowledge, have not been previously reported. Results from this study suggest that posterior global alignment may be related to a lack of restoration of TK during the surgical procedure. The posterior alignment group has significantly lower TK change than the 2 other groups (5° *vs*. 11°, $P = 0.038$). The reasons for this finding remain unclear although several potential explanations can be advanced. Rose *et al*[24] reported that TK was not altered postoperatively in patients fused to T5 or cephalad after lumbar PSO, while patients fused caudal to T5 demonstrated significantly increased postoperative TK. These reciprocal changes occurred in the unfused spinal segment and may affect postoperative sagittal alignment.[26] However, in our series, differences in terms of upper instrumented vertebrae were not significant, and thus, thoracic reciprocal changes do not explain cases of posterior alignment. Another surprise encountered in this study was the frequent occurrence of previous surgical procedures. Although, it could be assumed that previous intervention would limit the ability to obtain a satisfactory postoperative alignment, previous surgery was not a factor that could explain postoperative alignment variations as no significant difference in terms of surgical status (primary *vs*. revision) was observed between groups.

Interestingly, in our study, all patients globally underwent rather similar surgical procedures despite various preoperative differences among the 3 groups (anterior alignment, neutral alignment, and posterior alignment). Although preoperative regional alignment (TK and LL) was not significantly different between groups, patients classified as having a posterior alignment were younger and showed a significantly smaller PI-LL mismatch. This point is important because it relates to the amount of correction needed for these different groups and underlines the need for a patient-specific preoperative surgical plan. In other words, this result suggests that patients in the posterior alignment group, while presenting a preoperative global sagittal deformity, required significantly less correction than patients in the 2 other groups (greater PI-LL mismatch) and yet received a similar realignment operation.

Operative setup can affect the ability to obtain a desired sagittal plane correction surgically. A potential source for the lack of lordosis restoration can be directly attributed to patient positioning. Harimaya *et al*[27] have reported that prone positioning increases LL for patients with preoperative hypolordosis. Identical positioning of patients with a small *versus* large, PI could potentially be a source of correction error due to the fact that these patients require less lordosis change than the others to reach a satisfactory PI-LL harmony, despite the same value of preoperative LL. Inappropriate operative positioning could also be a source of decreased TK.

Although this study was not specifically intended to provide patient-specific preoperative surgical plan, it can be used as a general guideline for realignment procedures. According to our findings, it is crucial to obtain preoperative full-spine radiographs including the femoral heads in order to measure PI, PT, LL, TK, and sagittal vertical axis. According to these values, the amount of the osteotomy resection angle can be evaluated, understanding that patients with a smaller PI and PI-LL mismatch will require a smaller osteotomy resection angle.

Another difficulty is the ability to execute the preoperative surgical plan intraoperatively. One potential solution is to obtain an intraoperative long cassette radiograph that will allow measurement of the lumbar and thoracic spinal alignment while the patient is on the operating table. By reviewing this intraoperative radiograph, the surgeon will be able to visualize the PI, assess the PI-LL mismatch intraoperatively, and adapt the degree of the osteotomy resection angle while also analyzing the TK.

The clinical impact of global posterior sagittal plane alignment is difficult to evaluate precisely. Results from a limited follow-up study revealed that patients with a negative C7 sagittal plumb line seem to have better clinical outcomes[8] than patients with a neutral or positive C7 sagittal plumb-line. On the other hand, posterior alignment related to a lack of TK can lead to subsequent cervical kyphosis in order to maintain horizontal gaze. Such results were reported in patients with AIS by Hilibrand *et al*[28] who showed a significant correlation between loss of TK and development of cervical kyphosis. In this study, we were able to show correlations between SVA and sagittal parameters pre- and postoperatively. Results from this correlation study confirmed the role of pelvic retroversion (increased PT) as a compensatory mechanism to maintain the position of the head over the pelvis. Furthermore, pre- and postoperative modifications of CL (increasing with anterior malalignment and decreasing with negative SVA) indicate that to maintain a horizontal gaze, patients compensate with their cervical spine.

It is important to underline that the limited follow-up time may not reveal the detrimental clinical impact of a loss of CL. However, cervical hypolordosis (<20°) has been correlated with an increased risk of neck complaints.[29] Long-term follow-up and correlation with clinical scores will therefore be necessary to assess the progression of the patients with a posterior alignment from this study to determine ultimate impact of the loss of CL and guide improved realignment planning strategies.

CONCLUSION

Despite limitations due to its retrospective design and limited follow-up, this study analyzed an ASD population for factors leading to posterior alignment. Although preoperative planning is crucial, one of its limitations is our ability to turn this planning into intraoperative execution, underlining the necessity for obtaining intraoperative assessment of lumbar and thoracic spinal alignment (full length radiographs). Results from this study support the use of patient specific guidelines for patients with a small PI-LL mismatch, for whom a smaller realignment procedure is needed and for whom specific attention must be paid to restore a satisfactory TK.

➢ Key Points

- ❑ Sagittal plane alignment has been established as a key driver of disability. Optimal alignment criteria have been reported as an SVA < 50 mm, PT < 25° and PI-LL < 10°.
- ❑ While postoperative anterior global malalignment is associated with poor outcomes, little is known of the cause and impact of posterior global malalignment.
- ❑ Results from this study demonstrate that patients with posterior global malalignment after surgery were significantly different based on spinopelvic baseline radiographical values (*vs*. anterior global malalignment group) but received identical realignment procedures.
- ❑ Postoperative posterior global malalignment was related to a lack of spinopelvic harmony, TK restoration, and was associated with a compensatory loss of CL.
- ❑ This study underlines the crucial importance of patient specific preoperative planning for realignment procedures.

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