Analysis of risk factors for loss of lumbar lordosis in patients who had surgical treatment with segmental instrumentation for adolescent idiopathic scoliosis

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Abstract

Purpose Iatrogenic flattening of lumbar lordosis in patients with adolescent idiopathic scoliosis (AIS) was a major downside of first generation instrumentation. Current instrumentation systems allow a three-dimensional scoliosis correction, but flattening of lumbar lordosis remains a significant problem which is associated with decreased health-related quality of life. This study sought to identify risk factors for loss of lumbar lordosis in patients who had surgical correction of AIS with the use of segmental instrumentation.

Methods Patients were included if they had surgical correction for AIS with segmental pedicle screw instrumentation Lenke type 1 or 2 and if they had a minimum follow-up of 24 months. Two groups were created, based on the average loss of lumbar lordosis. The two groups were then compared and multivariate analysis was performed to identify parameters that correlated to loss of lumbar lordosis.

Results Four hundred and seventeen patients were analyzed for this study. The average loss of lumbar lordosis at 24 months follow-up was an increase of 10° lordosis for group 1 and a decrease of 15° for group 2. Risk factors for loss of lumbar lordosis included a high preoperative lumbar lordosis, surgical decrease of thoracic kyphosis, and the particular operating surgeon. The lowest instrumented vertebra or

spinopelvic parameters were two of many parameters that did not seem to influence loss of lumbar lordosis.

Conclusion This study identified important risk factors for decrease of lumbar lordosis in patients who had surgical treatment for AIS with segmental pedicle screw instrumentation, including a high preoperative lumbar lordosis, surgical decrease of thoracic kyphosis, and factors attributable to a particular operating surgeon that were not quantified in this study.

Keywords AIS · Sagittal balance · Segmental instrumentation · Pelvic tilt · Lumbar lordosis

Introduction

Segmental instrumentation for the surgical treatment of adolescent idiopathic scoliosis (AIS) was developed to provide a more stable construct, compared to the previously used Harrington rod. Another advantage was the ability for three-dimensional curve correction with specific focus on restoring thoracic kyphosis and lumbar lordosis [1, 2]. The latter has been identified to have a direct correlation to health-related quality of life [3–5]. Patients with a significant loss of lumbar lordosis often require an energy consuming and subsequently painful compensatory mechanism such as pelvic retroversion to restore the gravity line [4–6].

The concept of spinopelvic compensatory mechanism was promoted by some French authors more than 20 years ago, but it was not until the last decade when the first studies regarding this topic were published in the English literature [7–10]. Since then, an almost exponential increase in publications proved the significance of research dealing with the sagittal profile of the spine, and not only in patients with AIS.

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Today, it is well recognized that instrumentation with the Harrington rod into the lower lumbar spine leads to a significant loss of lumbar lordosis, further leading to a specific description known as the Flat Back syndrome [11, 12]. While probably the most significant risk factor for a flat back after surgical treatment for AIS—the Harrington rod—has been abandoned, there may still be patients with severely flat backs despite the use of segmental instrumentation. Although to our knowledge this hypothesis has not been formally investigated, many surgeons will agree that they are aware of such cases. An example is provided in Fig. 1.

An increasing incidence of flat back can be expected with more and more patients with long-term follow-up.

To date, dozens of studies have been published on the importance of choosing instrumentation levels to have the shortest instrumentation with the best possible correction with respect to the coronal plane. Such studies discuss stable and neutral vertebrae, coronal tilt of end vertebrae, selective thoracic fusion, and a variety of additional parameters that can be measured on straight and side bending radiographs [13–16]. There is a paucity of studies which analyze how to restore appropriate lumbar lordosis. The majority of these studies analyze sagittal thoracic changes with the use of multisegmental instrumentation without respect to demographic, spinopelvic, or surgeon controlled parameters [2, 17–19]. The aim of the present study is to analyze whether any independent risk factors for loss of lumbar lordosis can be identified. Identifying such a risk factor will facilitate surgical planning in patients with AIS, specifically with respect to the important sagittal profile.

Methods

In this multicenter study, patients with surgical treatment for AIS were identified and enrolled prospectively. IRB approval was obtained for each site prior to data collection. Patients with posterior segmental instrumentation for Lenke type 1 and 2 curves and 24 months follow-up were included for this study.

Retrospective radiographic analysis was performed on lateral erect standing roentgenograms of the entire spine by one of two experienced investigators who were blinded to the purpose of this study (intra rater variability ranges 0.976–0.992, inter rater agreement is 0.981; The upper bound of the 95 % CI for the standard error of measurement is 4° for the inter- and intra rater error).

Change in lumbar lordosis was calculated and patients were assigned to one of two groups based on the average loss of lumbar lordosis for the whole patient population (+2.9°). Patients with less than a 3° decrease in lumbar lordosis were defined as “no change/increase” of lumbar

Fig. 1 32-year-old female 18 years following posterior spinal fusion with segmental instrumentation. The patient suffers from a decompensated sagittal imbalance. There is a positive sagittal vertical axis despite an increased pelvic tilt (case is not from the study population)

lordosis; patients with more than a 3° decrease in lumbar lordosis were classified as “loss of lordosis.”

The groups were then compared with regards to gender, age, lowest instrumented vertebra, rod material, preoperative pelvic incidence, preoperative lumbar lordosis, preoperative thoracic kyphosis from T2 to T12, amount of thoracic kyphosis correction, and surgeon.

Statistical methods

Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL) was used to conduct the analyses. Descriptive

statistics for the radiographic variables were calculated. Univariate logistic regression was utilized to determine which variables were independently predictive for loss of lordosis. Each variable that was found to be significantly correlated ($p < 0.05$) was entered into a multivariate logistic regression analysis to determine the most significant predictors in a multivariate model. Alpha was set at $p < 0.05$.

Results

Four hundred and seventeen patients (313 girls and 104 boys) met all inclusion criteria and were analyzed for this study. 253 patients underwent selective thoracic fusion with the lowest instrumented vertebra (LIV) = L1 or above (T8 = 1, T9 = 3, T10 = 4, T11 = 34, T12 = 93, L1 = 118) and 164 patients had their fusion extended into the lumbar spine with the LIV = L2 or below (L2 = 88, L3 = 61, L4 = 15).

The average preoperative lumbar lordosis was 59° (range 20° to 95°), and the average loss of lumbar lordosis after 24 months was 3° as defined by our methodology. The average change of lordosis for each group was an increase of 10° (range -2° to 40°) versus a loss of 15° (-3° to 43°) ($p < 0.001$). The average preoperative thoracic kyphosis was 31° (range -17° to 76°), and the average operative change of thoracic kyphosis was a decrease of 2° (range, -43° to 34°). For each degree of lost thoracic kyphosis, the risk of having above-average loss of lumbar lordosis increases by 13 %. Pelvic tilt averaged 11° (range -12° to 57°), and pelvic incidence averaged 53° (range 28° to 93°).

Univariate logistic regression analysis failed to identify significant differences between the two groups for age at surgery, gender, body mass index, preoperative pelvic incidence, preoperative pelvic tilt, and surgeon ($N = 22$).

Univariate logistic regression analysis identified significant differences between the two groups for preoperative thoracic kyphosis ($p < 0.001$), operative change of thoracic kyphosis ($p < 0.001$), preoperative lumbar lordosis ($p < 0.001$), LIV ($p = 0.007$), and rod material ($p = 0.03$). Additionally, a subanalysis of the influence of the specific surgeon was performed because we believed that the initial analysis that included 22 surgeons might have been underpowered. We therefore analyzed only those surgeons who met an inclusion criterion of contributing at least 25 cases to the database (five surgeons, 286 cases). The analysis identified that the operating surgeon was a significant factor associated with the loss of lumbar lordosis ($p = 0.03$).

Multivariate logistic regression analysis confirmed significance for the operative change of thoracic kyphosis ($p = 0.005$; odds ratio 1.13; Fig. 2), for the preoperative

Fig. 2 Operative change of thoracic kyphosis in relation to change of lumbar lordosis

Fig. 3 Preoperative lumbar lordosis in relation to change of lumbar lordosis

lumbar lordosis ($p = 0.002$, odds ratio 1.1; Fig. 3), and for surgeon after the subanalysis (1 of 5 surgeons with an odds ratio of 1.99, $p = 0.018$). The significant differences from the univariate logistic regression analysis for preoperative thoracic kyphosis, rod material, and LIV did not remain significant in the multivariate logistic regression analysis.

Discussion

In the current study we compared two groups with respect to loss of lumbar lordosis after segmental instrumentation for AIS. The groups were created based on the average loss of lumbar lordosis for the total population. We calculated

an average difference of 25° between the groups and identified three significant risk factors that are associated with the loss of lumbar lordosis after surgical treatment for AIS:

1. *Operative change of thoracic kyphosis.* Patients whose thoracic kyphosis is flattened surgically are at higher risk of having above-average loss of lumbar lordosis. For each degree of lost thoracic kyphosis, the risk of having above-average loss of lumbar lordosis increases by 13 %.
2. *Preoperative lumbar lordosis.* Patients with a high preoperative lumbar lordosis are at risk for having above-average loss of lumbar lordosis.
3. *Surgeon.* Patients from specific surgeons are at risk of having above-average loss of lumbar lordosis. The reason for this risk factor was not analyzed in this study. Potential explanations may be the amount of lumbar lordosis a surgeon bends into the rod or the use of osteotomies to increase thoracic kyphosis.

Our study excluded two surgeon-controlled parameters as risk factors for loss of lordosis: LIV and rod material. Although there are no studies specifically looking at LIV and lumbar lordosis, the majority of authors who comment on ideal instrumentation levels have always focused on the LIV and have tried to keep the instrumentation as short as possible. Rod stiffness has also not specifically been analyzed in previous studies. Intuitively, higher rod stiffness should maintain thoracic hypokyphosis correction, which will eliminate one of our identified risk factors (decrease of thoracic kyphosis). Although our study was not able to confirm this, it was probably underpowered for this specific question since there were only a few patients with 24-month follow-up treated with rods of newer, stiffer metallurgy such as cobalt–chrome.

Pelvic incidence and pelvic tilt were also not identified as risk factors for loss of lumbar lordosis. Pelvic incidence represents an anatomic description of the spinopelvic alignment and often determines the amount of lumbar lordosis. Pelvic tilt is a compensatory mechanism to keep the gravity line centered [5, 9]. Some authors recommend including the spinopelvic parameters into surgical planning in spinal deformity. However, our data were not able to support their relevance, at least for surgical planning in AIS. Demographic characteristics do not seem to have any influence on postoperative lumbar lordosis.

Tanguay et al. [10] analyzed the influence of spinopelvic alignment on pre- and postoperative lumbar lordosis in 60 patients who underwent segmental surgical correction for AIS and had 6 months follow-up. The authors observed a high relation between the pelvic incidence and the lumbar lordosis. The authors of the current study therefore recommend including the pelvic incidence in the surgical

planning, which may facilitate determining the optimal lumbar lordosis, specifically for patients with very high pelvic incidence ($>80^\circ$). In our study, pelvic incidence was not identified as a risk factor for loss of lumbar lordosis. However, a separate analysis of patients with very high pelvic incidence may unmask loss of lordosis in this patient population. Unfortunately, our patient population does not have enough patients with a pelvic incidence of $>80^\circ$ to allow for this subanalysis. Although we have not identified spinopelvic alignment to be a risk factor for loss of lordosis, we also believe in the importance of considering spinopelvic alignment in surgical planning for AIS.

De Jonge et al. [2] analyzed the sagittal outcome after surgical treatment of AIS with a multisegmental hook system. The authors observed that all patients with a preoperative lumbar lordosis of $>60^\circ$ had an average 25° decrease in lumbar lordosis postoperatively. In other words, de Jonge et al. also identified high preoperative lumbar lordosis as a risk factor for postoperative lumbar lordosis. However, perhaps the loss of lumbar lordosis was intended because the authors considered patients with lumbar lordosis of $>60^\circ$ to have hyperlordosis, which needed to be corrected.

Improving thoracic kyphosis to maintain or improve lumbar lordosis has been recommended by previous authors [2, 10, 16, 19]. Newton et al. [17] reported that posterior segmental instrumentation for AIS significantly decreased thoracic kyphosis, which was also correlated to a loss of lumbar lordosis. Whereas thoracic kyphosis specifically decreased in the posterior approach group, this problem was not observed in patients who had anterior fusion. The authors therefore recommend posterior column lengthening for patients who undergo posterior spinal fusion with segmental instrumentation.

Mladenov et al. [19] observed an average decrease of thoracic kyphosis and lumbar lordosis of 8° and 12° , respectively, in patients who underwent selective posterior fusion for Lenke type 1 curves and additionally had a direct vertebral rotation, whereas patients who did not have an additional direct vertebral rotation maintained their preoperative thoracic kyphosis and lumbar lordosis. The initial descriptors of direct vertebral rotation, however, reported contrasting results, which reveal the potential importance of this specific surgeon controlled parameter for sagittal plane correction.

There are several limitations in this study that are not just due to its retrospective data analysis and multiple institutions being involved. This is a purely radiographic study, and no attempt was given to correlate the results with clinical outcome. We calculated a radiographic measurement error of 4° . However, due to the large number of patients, this error may have only limited influence on the results. Although the vast majority of patients received an

all-pedicle-screw construct, the type and the density of anchors were not further analyzed. This study is significant for the large number of patients, the prospective data collection, and the radiographic measurements performed by a blinded and centralized investigator.

With more understanding of the sagittal profile in scoliosis, several authors have recommended including lateral radiographic parameters in surgical planning. This study identified important risk factors for loss of lumbar lordosis, which will hopefully facilitate surgical planning for patients with AIS.

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Conflict of interest None.

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