Changes in lumbar lordosis after further spinal fusion of thoracic spine and its relationship to pelvic incidence

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Abstract

Objective: To evaluate the sagittal profile variables in patients with adolescent idiopathic scoliosis who underwent selective thoracic posterior spinal instrumentation and fusion with pedicle screws and to determine relationships among them.
Methods: Twenty consecutive patients were retrospectively evaluated. Changes in cervical lordosis, thoracic kyphosis, proximal junctional kyphosis, lumbar lordosis, pelvic incidence and global sagittal balance were compared in standing lateral radiographs performed before surgery, at the immediate postoperative period, and two years after surgery. Changes in postoperative lumbar lordosis were correlated with changes in thoracic kyphosis and pelvic incidence.
Results: There was a significant decrease in thoracic kyphosis and lumbar lordosis between preoperative and immediate postoperative radiographs, but both parameters showed an increase in the radiographs two years later. A significant increase in proximal junctional kyphosis and cervical lordosis was also found between preoperative and 2-year postoperative radiographs. The only significant postoperative correlation found was between lumbar lordosis and pelvic incidence at 2-year follow-up control.
Conclusions: Posterior spinal instrumentation and fusion with pedicle screws in Lenke type 1 deformities reduces thoracic kyphosis and lumbar lordosis, and increases cervical lordosis and proximal junctional kyphosis. Uninstrumented lumbar lordosis increased at 2-year follow-up and it is strongly related to the pelvic incidence.

Key words: Lumbar lordosis; posterior spinal fusion, adolescent idiopathic scoliosis, pedicle screws.
Level of Evidence: IV

Cambios en la lordosis lumbar luego de una artrodesis vertebral posterior de la columna torácica y su relación con la incidencia pelviana

Resumen

Objetivo: Evaluar las variables del plano sagital en pacientes con escoliosis idiopática del adolescente tratados mediante una artrodesis vertebral posterior instrumentada con tornillos pediculares y establecer relaciones entre ellas.
Materiales y Métodos: Se evaluó retrospectivamente a 20 pacientes. Se compararon los cambios en la lordosis cervical, la cifosis torácica, la lordosis lumbar, la incidencia pelviana, el balance sagital global y la cifosis de la unión proximal en

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los espinogramas preoperatorio, posoperatorio inmediato y a los dos años de la cirugía. Se correlacionaron los cambios en la lordosis lumbar con la cifosis torácica y la incidencia pelviana.
Resultados: Se observó una disminución significativa en la cifosis torácica y en la lordosis lumbar en el espinograma posoperatorio inmediato. Ambos parámetros mostraron un aumento en el espinograma a los dos años. Se halló un aumento significativo en la cifosis de la unión proximal y en la lordosis cervical entre el preoperatorio y el posoperatorio a los dos años. La única correlación posoperatoria significativa fue entre la lordosis lumbar y la incidencia pelviana en el espinograma a los dos años de la cirugía.
Conclusiones: La artrodesis vertebral posterior instrumentada con tornillos pediculares en curvas Lenke 1 provoca una reducción posoperatoria de la cifosis torácica y de la lordosis lumbar, y un aumento posoperatorio de la lordosis cervical y de la cifosis de la unión proximal. A los dos años, se observó un aumento de la lordosis lumbar no instrumentada, y que dicha lordosis lumbar se correlaciona significativamente con la incidencia pelviana.

Palabras clave: Lordosis lumbar; artrodesis vertebral posterior; escoliosis idiopática del adolescente; tornillos pediculares.
Nivel de Evidencia: IV

Introduction

Adolescent idiopathic scoliosis (AIS) results in a three-dimensional spinal deformity. Its surgical approach aims at correcting this deformity by a solid and stable spinal fusion that is three-dimensionally well-balanced, i.e. on the frontal, the sagittal and the transverse planes. The first instrumentation devices used to correct scoliosis by posterior spinal distraction, what improved the frontal plane whereas impairing the normal spinal kyphosis and lordosis.[1] Current instrumentation devices perform a segmental spinal fusion that allows correction on the frontal plane using a posterior approach while recovering the normal sagittal and transverse spinal balance. Over the past few years, pedicle screws have gained great popularity in segmental spinal fusion using a posterior approach. One of the drawbacks to pedicle screws is the lordosis effect that they produce on the thoracic spine.[2-4] This may stem from the greater correction and elongation produced in the frontal plane using this instrumentation as compared with other fixation systems.[2,3] Some authors[4,5] have suggested that this lordosis effect on the thoracic spine might impair normal lordosis at the level of the lumbar spine with no instrumentation.

They conclude that, at the time of fusing the thoracic spine, it is essential to preserve thoracic kyphosis in order to keep the normal lumbar lordosis. On the contrary, other authors affirm that lumbar lordosis depends on the pelvic incidence inherent in every patient rather than thoracic kyphosis, both in patients with no spinal deformity[6] and in patients with AIS[7], and also in those that have undergone instrumented posterior spinal fusion (PSF) in the thoracic spine for AIS.[8]

The aim of this work is to assess the sagittal plane variables in patients with AIS who have been operated on using instrumented PSF with pedicle screws, and to prove the relationship that exists between them.

Materials and Methods

This study includes: 1) patients with AIS and Lenke type I thoracic curves[9], 2) operated on using instrumented PSF with pedicle screws, 3) whose lowest instrumented vertebra is T12 or L1, 4) with a minimal 2-year postoperative follow-up, and 5) three digital spinograms (taken before the surgery, in the immediate postoperative period and two years after the surgery) that include the whole cervical spine and both femoral heads. Patients with: 1) a previous spinal surgery 2) an anterior approach added to the posterior approach 3) hip or pelvic disorders, or unequal leg length or 4) associated spondylosis or spondylolisthesis were excluded.

The X-ray evaluation includes three digital lateral spinograms that were taken: 1) immediately before the surgery 2) within the first month following the instrumented PSF, and 3) two years after the surgery. Parameters analyzed on the saggital plane are: 1) the global saggital balance regarding C7 and the sacral antero-posterior angle, 2) cervical lordosis from the C2 caudal end-plate to the C7 caudal end-plate, 3) thoracic kyphosis from the T5 cranial end-plate to the T12 caudal end-plate, 4) lumbar lordosis from the L1 cranial end-plate to the S1 cranial end- plate, 5) the pelvic incidence, and 6) the proximal junctional kyphosis of the instrumentation (from the caudal end- plate of the upper instrumented vertebra to the cranial end- plate of the second vertebra cranial to the upper instrumented vertebra).

Changes occurred in every parameter analyzed on the sagittal plane were compared in different postoperative periods (immediate postoperative spinogram and spinogram taken two years after the surgery) with the preoperative values. Moreover, the postoperative changes occurred in lumbar lordosis were correlated with the postoperative changes in thoracic kyphosis and the pelvic incidence in the two postoperative evaluations (immediate postoperative spinogram and spinogram taken two years after the surgery).

Statistical Analysis

For statistical analysis we used the EPI info program version 3.3.2 with a significance level of 0.05. For comparative statistical analysis of preoperative and postoperative results we used the Student's t-test and, for correlation between the different parameters assessed, we used the Pearson's correlation coefficient.

Results

We evaluated retrospectively 20 patients that met the criteria (19 female patients and one male patient). Average age at the time of surgery was 14 years old (ranging from 10 to 25). As described by the Lenke classification,[9] nine patients showed a lumbar A variable, six, a lumbar B variable and, five, a lumbar C variable. On the sagittal plane, 14 patients showed a normal thoracic saggital variable (thoracic kyphosis between 10° and 40°) and six, a positive thoracic saggital variable (thoracic kyphosis >40°). The lowest instrumented vertebra was T12 in three patients and L1 in 17 patients. In two patients, spinal fusion involved nine vertebral levels; in five patients, 10 levels and, in 13 patients, 11 levels. The correction techniques used were rod derotation, *in situ* rod modeling, segmental compression-distraction of the spinal anchor points, and direct spinal derotation of the deformity apex screws. Implant average density per instrumented vertebra was 1.72 (ranging from 1.63 to 1.91).

Table 1 shows the results of preoperative and postoperative X-ray evaluations. We found a significant increase in the average value of cervical lordosis and the proximal junctional kyphosis of respectively 10.6° and 7.3° two years after the surgery. Nine of the 20 patients (45%) showed a >10° increase in thoracic kyphosis between the preoperative period and the 2-year postoperative follow-up. Moreover, we found a significant loss of thoracic kyphosis of 9.4° in the immediate postoperative period, which two years after the surgery was of 5.5° with respect to the average preoperative values. Lumbar lordosis also decreased significantly—some 20.5° in the immediate postoperative period; the loss improved, showing only 7.9° two years after the surgery.

Tables 2 and 3 show the correlation between the variables evaluated respectively in the immediate postoperative period and two years after the surgery. The variables evaluated in the spinograms taken in the immediate postoperative periods show a good correlation between thoracic kyphosis and lumbar lordosis. Moreover, they show a moderate correlation between thoracic kyphosis and the pelvic incidence. The correlation between thoracic kyphosis and lumbar lordosis was minimal. The correlation between the pelvic incidence and lumbar lordosis

Table 1. Preoperative, immediate postoperative and 2-year postoperative values

	Preoperative period	Immediate postoperative period		Two-year postoperative period	
Cervical lordosis	-4.2° ± 17.5°	-6.5° ± 14,7°	p = 0.57	-14.8° ± 17,3°	p = 0.025
Proximal junctional kyphosis	5.1° ± 6.1°	6.2° ± 6.7°	p = 0.49	12.4° ± 5.1°	p <0.0001
Thoracic kyphosis	24.2° ± 10.4°	14.8° ± 7.3°	p <0.0001	18.7° ± 6.9°	p = 0.021
Lumbar lordosis	-60.3° ± 11,6°	-39.8° ± 9.1°	p <0.00001	-52.4° ± 10°	p = 0.0036
Pelvic incidence	52.5° ± 13.2°	49.6° ± 15°	p = 0.16	49.6° ± 12.8°	
Global sagittal balance	-30.7 mm ± 22.3	-3 ± 24 mm	p = 0.0008	-20.8 ± 28.1 mm	p = 0.12

Table 2. Correlation between the variables evaluated in the immediate postoperative spinogram

	Proximal junctional kyphosis	Thoracic kyphosis	Lumbar lordosis	Pelvic incidence
Cervical lordosis	0.161	-0.6235 (p = 0.0033)	0.1305	-0.0781
Proximal junctional kyphosis		-0.1314	-0.3043	-0.1869
Thoracic kyphosis			-0.1277	-0.436
Lumbar lordosis				-0.3466

Table 3. Correlation between the variables evaluated in the 2-year postoperative spinogram

	Proximal junctional kyphosis	Thoracic kyphosis	Lumbar lordosis	Pelvic incidence
Cervical lordosis	0.0164	-0.4265	0.0484	-0.0073
Proximal junctional kyphosis		-0.3278	-0.1127	0.1079
Thoracic kyphosis			-0.0241	-0.2861
Lumbar lordosis				-0.6107 (p = 0.0042)

was low. Finally, two years after the PSF, correlation was good only between the pelvic incidence and lumbar lordosis. There was a moderate correlation between thoracic kyphosis and cervical lordosis, and a low correlation between thoracic kyphosis and the proximal junctional kyphosis, and also between thoracic kyphosis and the pelvic incidence. Between thoracic kyphosis and lumbar lordosis, the correlation was minimal.

Discussion

In our series of 20 patients with AIS treated by instrumented PSF with pedicle screws, we saw a significant decrease in thoracic kyphosis and lumbar lordosis in the immediate postoperative spinogram. Several authors have reported this lordosis effect on the thoracic spine of patients operated on with pedicle screws using a posterior approach.[2-4]However, this lordosis effect on the thoracic spine has also been reported with the use of other posterior fixation systems, both in hybrid systems,[2] and in systems using only pedicle and laminar hooks in every spinal fixation point.[10] This thoracic lordosis effect of spinal corrections using a posterior approach has already been suggested by Newton et al.[4] and it may be related to the spinal elongation performed while correcting the deformity using posterior instrumentations. Continuing this line of though, it is reasonable to expect that pedicle screws cause a lordosis effect on the thoracic spine because correction on the frontal plane is remarkable,[2,11] with greater spinal elongation and, therefore, a greater lordosis effect. On the contrary, with anterior spinal instrumentations, the deformity is corrected by spinal shortening, so, thoracic kyphosis increases. [10,12,13]

In our series, we verified an increase in both thoracic kyphosis and lumbar lordosis in the PSF 2-year postoperative follow-up spinogram. This increase was greater in lumbar lordosis (12.6°) than in thoracic kyphosis (3.9°). Other studies also showed an increase in both parameters some years after the posterior fusion.[4,5] These authors have even related these changes in the uninstrumented lumbar lordosis to the changes seen at the level of the instrumented thoracic spine. They concluded that the loss of lumbar lordosis both in the immediate postoperative period and two years after the surgery may stem from the loss of thoracic kyphosis in these patients.[4,5] Newton et al.[4] report a low correlation (r = 0.3) in the immediate postoperative period and a moderate correlation (r = 0.4) two years after the surgery. Meanwhile, Khakinahad et al.[5] found a moderate correlation between these values both in the immediate postoperative period (r = 0.47) and after two years (r = 0.5). In our series, we found a minimal correlation between these two values in the immediate postoperative spinograms (r = 0.1277) and two years after the surgery (r = 0.0241). In our patients, the changes in the postoperative lumbar lordosis showed a better correlation with the pelvic incidence (r = 0.3466 in the immediate postoperative period and r = 0.6107 two years after the surgery) than with thoracic kyphosis. However, the aforementioned two studies[4,5] did not determine the pelvic incidence in the patients of their series and, therefore, did not correlate the changes in lumbar lordosis with the pelvic incidence so as to compare the correlation between lumbar lordosis and the pelvic incidence with the correlation reported between thoracic kyphosis and lumbar lordosis. Unlike these two works, Tanguay et al.[8] published a study in which, besides thoracic kyphosis and lumbar lordosis, they assessed the pelvic incidence and, as in results in our series, they found a better correlation between the pelvic incidence and the postoperative changes occurred in lumbar lordosis (r = 0.67) than between changes in postoperative thoracic kyphosis and lumbar lordosis (r = 0.12). They conclude that every patient presents an individual value of lumbar lordosis that depends mainly on his or her pelvic geometry. In this context, this initial loss of lumbar lordosis may be associated with the posterior approach and the approach through the paravertebral muscles rather than the type of instrumentation or the loss of postoperative thoracic kyphosis. On the other hand, it is possible that other factors that have not been assessed are also involved in this immediate postoperative loss of lumbar lordosis because Newton et al. [4] also show in their study this immediate postoperative loss of lumbar lordosis in the group of patients treated using an anterior approach that caused a kyphosis effect on the thoracic spine in the immediate postoperative period.

Moreover, in our series we detected a significant increase in the proximal junctional kyphosis and cervical lordosis in the 2-year postoperative period, results that

have also been reported by other authors.[14,15] These changes may be related to the decrease in the postoperative thoracic kyphosis, because we found a moderate correlation between the changes occurred in thoracic kyphosis and cervical lordosis (r = 0.4265) and a low correlation between thoracic kyphosis and the proximal junctional kyphosis (r = 0.3267). The loss of thoracic kyphosis could be compensated for by an increase of the proximal junctional kyphosis and cervical lordosis.

Results in our population suggest that the uninstrumented spinal segments, after a selective thoracic fusion try to compensate for the changes occurred in the near caudal segments. This way, we found that, although there is an immediate postoperative loss of lumbar lordosis, which has been described by several authors regardless the approach and the instrumentation system used,[4,5,10] with time lumbar lordosis increases trying to reach the preoperative values. These changes in our population showed a good correlation with the pelvic incidence inherent in every patient and a correlation almost null with his or her postoperative thoracic kyphosis. It would be interesting to re-evaluate these patients in a few years to verify if lumbar lordosis keeps increasing until finally reaches the preoperative values. Although changes in thoracic kyphosis seem not to be related to changes in lumbar lordosis, changes in thoracic kyphosis may certainly determine an increase in the proximal junctional kyphosis and in cervical lordosis, because in our patients, the postoperative loss of thoracic kyphosis showed a better correlation with the increase in cervical lordosis and the proximal junctional kyphosis than with the postoperative changes in lumbar lordosis. This study should be implemented also in a population of patients operated on using diverse approaches and different instrumentation systems so as to verify that the changes and correlations seen in this study are repeated in patients treated in a different way.

This is a retrospective study, so, although all X-rays were taken at the same Center for Diagnostic Imaging, there could have been a few variations in the position of patients, what may alter the evaluations result. Another weakness is the low number of patients, but we chose to carry out a study based on a consecutive and uniform population in which every patient has been operated on by the same surgical team using the same surgical technique.

Conclusions

The instrumented PSF with pedicle screws in patients with Lenke 1 curves causes a postoperative decrease in thoracic kyphosis and lumbar lordosis, and a postoperative increase in cervical lordosis and the proximal junctional kyphosis. In X-rays taken two years after the surgery, we found an increase in the uninstrumented lumbar lordosis as compared to the immediate postoperative values, and also that uninstrumented lumbar lordosis is significantly related to the patient's pelvic incidence.

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