REV BRAS ORTOP. 2016;51(1):83–89

RBO REVISTA BRASILEIRA DE ORTOPEDIA

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Original Article

Assessment of spontaneous correction of lumbar curve after fusion of the main thoracic in Lenke 1 adolescent idiopathic scoliosis☆

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ARTICLE INFO

Article history:
Received 17 December 2014
Accepted 23 March 2015
Available online 13 January 2016

Keywords:
Scoliosis
Bone screws
Treatment outcome

ABSTRACT

Objective: To evaluate the clinical and radiographic response of the lumbar curve after fusion of the main thoracic, in patients with adolescent idiopathic scoliosis of Lenke type 1.
Methods: Forty-two patients with Lenke 1 adolescent idiopathic scoliosis who underwent operations via the posterior route with pedicle screws were prospectively evaluated. Clinical measurements (size of the hump and translation of the trunk in the coronal plane, by means of a plumb line) and radiographic measurements (Cobb angle, distal level of arthrodesis, translation of the lumbar apical vertebral and Risser) were made. The evaluations were performed preoperatively, immediately postoperatively and two years after surgery.
Results: The mean Cobb angle of the main thoracic curve was found to have been corrected by 68.9% and the lumbar curve by 57.1%. Eighty percent of the patients presented improved coronal trunk balance two years after surgery. In four patients, worsening of the plumb line measurements was observed, but there was no need for surgical intervention. Less satisfactory results were observed in patients with lumbar modifier B.
Conclusions: In Lenke 1 patients, fusion of the thoracic curve alone provided spontaneous correction of the lumbar curve and led to trunk balance. Less satisfactory results were observed in curves with lumbar modifier B, and this may be related to overcorrection of the main thoracic curve.

Avaliação da correção espontânea da curva lombar após a fusão da torácica principal na escoliose idiopática do adolescente Lenke 1

Palavras-chave:
Escoliose

RESUMO

Objetivo: Avaliar a resposta clínica e radiográfica da curva lombar após a fusão da torácica principal, em pacientes com escoliose idiopática do adolescente (EIA) Lenke 1.

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http://dx.doi.org/10.1016/j.rboe.2015.03.013

Parafusos ósseos
Resultado de tratamento

Métodos: Foram avaliados prospectivamente 42 pacientes portadores de EIA tipo Lenke 1 operados por via posterior com parafusos pediculares. Fizeram-se mensurações clínicas (tamanho da giba e translação do tronco no plano coronal pelo fio de prumo) e radiográficas (ângulo de Cobb, nível distal da artrodese, translação da vértebra apical lombar e Risser). As avaliações foram feitas no pré-operatório, pós-operatório imediato (POI) e dois anos após a cirurgia.

Resultados: Foi observada correção de 68,9%, em média, do ângulo de Cobb da curva torácica principal (TPR) e 57,1% da lombar. Oitenta por cento dos pacientes apresentaram melhora do equilíbrio coronal do tronco, dois anos após a cirurgia. Em quatro pacientes foi observada piora dos valores da medida do fio de prumo, sem, entretanto, haver necessidade de nova intervenção cirúrgica. Os resultados menos satisfatórios foram observados em pacientes com modificador lombar B.

Conclusões: Em pacientes Lenke 1, a fusão exclusiva da curva torácica proporcionou correção espontânea da curva lombar e compensação do tronco. Os resultados menos satisfatórios foram observados em curvas com modificador lombar B e podem estar relacionados à hipercorreção da curva torácica principal.

Introduction

In cases of adolescent idiopathic scoliosis, the aim of surgical treatment is to provide compensation for the trunk and vertebral fusion for curvature that is considered to be structured. For this, the curvature is determined in accordance with the preoperative radiographic flexibility, and this guides the planning of the levels that are to undergo arthrodesis. King et al.[1] introduced the concept of selective thoracic arthrodesis in cases that were named “false double curves”. This concept has been refined over recent decades, especially consequent to the paper published by Richards in 1992.[2]

In 2001, Lenke et al.[3] published a two-dimensional classification of adolescent idiopathic scoliosis. In this, the curvature is grouped into six main types and is also described in terms of lumbar and sagittal modifiers. Lenke type I is the most frequent classification, and this only presents structuring of the main thoracic curve (TPR). There is a consensus in the literature that type 1A curvature should only receive fusion of the main thoracic curve. However, in types B and C, inclusion of the lumbar curvature (TL/L) is a matter of controversy. Moreover, with the evolution of operative techniques and instruments that have greater corrective power, it has been observed that greater interest has been taken in identifying factors that predict equilibrium or iatrogenic decompensation of the trunk after selective fusion of the spine.

The objective of the present study was to evaluate the clinical and radiographic correction of lumbar curvature and its predictive factors, after only performing fusion of the thoracic curve in patients with Lenke 1 adolescent idiopathic scoliosis.

Materials and methods

This study was approved by the institutional research ethics committee of the Catholic University of Santos (UNISANTOS) under the number CAAE 31602014.4.0000.5536. Forty-two patients with adolescent idiopathic scoliosis presenting curvature greater than 40° who underwent spinal arthrodesis participated in this study. They were evaluated clinically and radiographically in a prospective manner: before the operation, immediately after the operation (10 days afterwards) and after two years of follow up. All the patients were operated by the same senior surgeon. The clinical and radiographic evaluations were performed by members of the medical team who did not have direct participation in the research.

The following individuals were considered to be within the inclusion criteria: both genders; those with Lenke type 1 adolescent idiopathic scoliosis; those operated between the ages of 11 and 18 years; those with Cobb angles between 40° and 90°[4]; and those who underwent arthrodesis of the main thoracic spine by means of a posterior access route, using pedicle screws. Patients who required preoperative traction or distal fusion at L1 and those whose data were incompletely filled out were excluded.

The classification of the curves followed the criteria proposed by Lenke et al.[3] In this, the curves were classified into six main types, according to their structuring, and were also described in terms of a lumbar modifier (relationship between a central-sacral vertical line and the lumbar apical vertebra) and a sagittal modifier (kyphosis between T5 and T12).

Correction of the TPR followed the principles of derotation of the concavity with a rod by means of the technique of Cotrel and Dubousset.[5] This method was used in cases with lumbar A and B modifiers, as explained in the following: after placement of the pedicle screws, a previously molded concavity rod was positioned within the format of the scoliosis, followed by placement of fixation systems without completely locking them. At this time, the curve was corrected by means of derotation of the rod until it coincided with the kyphosis plane, or until the maximum correction in the coronal plane had been obtained. The correction finished with distraction between the screws and complete locking of the system. This was followed by placement of the second rod, which was molded in a rectified position with the aim of diminishing the thoracic hump and enabling fixation of this. In patients with the lumbar C modifier, a compression and distraction technique was used. In addition, deliberate undercorrection of the main thoracic curve was used, in order to minimize the risk of iatrogenic decompensation of the trunk.

The criteria of Suk et al.[6] were used to determine the fusion level. Thus, when a difference of up to two levels between the neutral vertebra and the terminal vertebra was observed, fusion was performed as far as the neutral vertebra and when this difference with greater than two levels, fusion was done as far as one vertebra before the neutral vertebra. Radiographs of the entire spine were produced on panoramic film (90 cm × 30 cm), in anteroposterior view (AP), lateral view (P) and active supine lateral oblique anteroposterior view.[7] The following parameters were evaluated as possible predictive factors for trunk compensation: Cobb angles of the proximal thoracic curve (TPX), TPR and TL/L[4]; Risser sign[8]; distal level of the arthrodesis; and translation of the lumbar apical vertebra.[9] The percentage correction of the curves was calculated in accordance with the formula proposed by Suk et al.[6]:

$$\frac{\text{Cobb pré-operatório} - \text{Cobb pós-operatório}}{\text{Cobb pré-operatório}} \times 100$$

$$\frac{\text{Preoperative Cobb} - \text{postoperative Cobb}}{\text{Preoperative Cobb}} \times 100$$

After this, ratio between the Cobb angle of the main thoracic curvature and the thoracolumbar/lumbar curvature was calculated.

The clinical measurements comprised the translation of the trunk in the coronal plane, measured using a plumb line (Scoliosis Research Society)[10] and the size of the lumbar hump (cm). These measurements were made during a maneuver of anterior inclination of the trunk.[11]

Statistical analysis

The patients' qualitative characteristics were evaluated and were described using absolute and relative frequencies. Their quantitative characteristics were described using summary measurements (mean, standard deviation, median, minimum and maximum).

The preoperative and postoperative scales were described using summary measurements and were compared between the times using paired Wilcoxon tests.[12] The scales evaluated before the operation, in the immediate postoperative period and two years after the operation were described and compared using Friedman tests,[12] followed by the multiple nonparametric comparisons for paired data that were proposed by Netter et al.[13]

Spearman correlations were calculated between the scales relating to two years after the operation in order to ascertain correlations in the final results from the patients, between the scales.[12]

Measurements of trunk equilibrium using a plumb line were described, along with thoracolumbar/lumbar Cobb angle values. After this, these values were correlated with the distal anatomical level of the arthrodesis (instrumented distal vertebra), by means of the Mann–Whitney test.[12] The preoperative and postoperative plumb line values and the scale of plumb line changes were compared with the three types of lumbar modifiers of Lenke et al., by means of the Kruskal–Wallis test.[12]

The tests were performed with a significance level of 5%.

Results

Among the 42 patients included in this study, 4 (9.5%) were male and 38 (90.5%) were female; 55% presented type 4 Risser sign at the time of the surgery. Their mean age was 11.9 years and 61.9% presented lumbar A modifier, 33.3% presented B and 4.8% presented C. The instrumented distal vertebra was T12 in 23.9% and L1 in 76.1% (Table 1).

The mean Cobb angle of the TPX was 24.69° (SD 7.34) and the lateral inclination was 13.07 (SD 7.56). In the immediate postoperative period, the mean TPX curvature was 12.57 (SD 6.84) and it was 12.64 (SD 6.89) two years after the surgery. A mean correction of 48.8% was observed.

For the main thoracic curvature (TPR) before the operation, the mean was 58.10° (SD 9.23) and the lateral inclination was 29.07° (SD 11.32). In the immediate postoperative period, the mean value observed was 15.90° (SD 6.46), while it was 18.02° (SD 6.91) two years after the procedure, i.e. an improvement of 68.9%.

The thoracolumbar/lumbar curvature (TL/L) presented a mean of 34.57° (SD 9.18) before the operation, with a lateral inclination of 8.07° (SD 11.09). In the immediate postoperative period, the value observed was 12.05° (SD 8.36) and after two

Table 1 – General characteristics of the sample.

Variable	Description ($n=42$)
Sex, n (%)	
Male	4 (9.5)
Female	38 (90.5)
Age at time of diagnosis (years)	
mean (SD)	11.95 (1.13)
median (min; max)	12 (11; 15)
Risser, n (%)	
1	3 (7.1)
2	4 (9.5)
3	10 (23.8)
4	23 (54.8)
5	2 (4.8)
Lenke, n (%)	
A	26 (61.9)
B	14 (33.3)
C	2 (4.8)
Arthrodesis level, n (%)	
Finished at L1	32 (76.1)
Finished at T12	10 (23.9)
Proximal thoracic lateral inclination	
mean (SD)	13.07 (7.56)
median (min; max)	13 (−6; 24)
Main thoracic lateral inclination	
mean (SD)	29.07 (11.32)
median (min; max)	30 (6; 56)
Thoracolumbar/lumbar lateral inclination	
mean (SD)	1.43 (11.09)
median (min; max)	2 (−29; 24)

Table 2 – Results from tests comparing before and after the operation.

Variable	Time	Mean	SD	Median	Minimum	Maximum	N	p
Hump (cm)	Before	2.23	0.92	2	0	4	42	<0.001[a]
	After	0.85	0.80	0.5	0	3	42	
Plumb	Before	1.25	1.23	1	0	5	42	<0.001[a]
	After	0.25	0.59	0	0	3	42	
Cobb AP proximal thoracic curve	Before	24.69	7.34	24.5	12	45	42	<0.001
	Immediately after	12.57	6.84	10.5	2	32	42	
	Two years after	12.64	6.89	10.5	2	30	42	
Cobb AP main thoracic curve	Before	58.10	9.23	58	44	91	42	<0.001
	Immediately after	15.90	6.46	15.5	1	28	42	
	Two years after	18.02	6.91	18	4	35	42	
Cobb AP thoracolumbar/lumbar curve	Before	34.57	9.18	34	17	54	42	<0.001
	Immediately after	12.05	8.36	10	0	35	42	
	Two years after	14.81	8.91	14.5	0	35	42	
Translation of thoracic apical vertebra	Before	49.83	16.49	50	17	95	42	<0.001
	Immediately after	11.36	6.95	10	2	33	42	
	Two years after	12.29	9.32	11	−4	45	41	
Translation of lumbar apical vertebra	Before	12.63	10.39	13	−5	46	41	0.866
	Immediately after	12.59	10.87	11	−3	33	41	
	Two years after	13.32	12.47	8	0	47	41	
Instrumented distal vertebra inclination	Before	24.78	6.64	24	11	45	41	<0.001
	Immediately after	6.07	3.96	5	1	17	42	
	Two years after	6.54	4.31	6	0	18	41	

Friedman test.

[a] Paired Wilcoxon test.

years it was 14.81 (SD 8.91), which represented spontaneous correction of the lumbar curvature of 57.1%.

The preoperative thoracic hump was 2.23 cm (SD 0.92) and it was 0.85 cm (SD 0.80) two years after the operation, i.e. an improvement of 61.8% ($p < 0.001$). The mean plumb line measurement was 1.25 cm (SD 1.23) before the operation and 0.25 cm (SD 0.59) after the surgical procedure, i.e. an improvement of 80% ($p < 0.001$).

The translation of the lumbar apical vertebra was the only parameter analyzed that did not present any statistically significant improvement ($p = 0.866$) (Table 2).

It was observed that there were statistically significant differences for the TPX, TPR and TL/L curvature, in comparing the pre and postoperative values ($p < 0.001$). The TPR and TL/L curvatures presented angular worsening regarding the values obtained in the immediate postoperative period and two years after the operation ($p = 0.006$ and $p = 0.005$, respectively) (Table 3).

Four patients presented worsening of their trunk equilibrium, as measured using a plumb line. Of these, two also presented increased lumbar humps. These cases were classified as Lenke A (one patient) and B (three patients). A description of the relationship between trunk compensation and the lumbar modifier is presented in Tables 4 and 5.

Also in relation to clinical measurements on the lumbar hump, according to each subtype of the lumbar modifier (A, B or C), we observed that there was no statistical difference between the groups, as presented in Table 6.

Table 3 – Comparisons between the evaluation times.

Variable	Comparison	Z value	p
Cobb AP proximal thoracic curve	Before vs. immed after	9.27	<0.001
	Before vs. two years after	8.55	<0.001
	Immed after vs. two years after	−0.71	0.476
Cobb AP main thoracic curve	Before vs. immed after	11.08	<0.001
	Before vs. two years after	8.36	<0.001
	Immed after vs. two years after	−2.72	0.006
COBB AP thoracolumbar/lumbar curve	Before vs. immed after	10.89	<0.001
	Before vs. two years after	8.10	<0.001
	Immed after vs. two years after	−2.79	0.005
Translation of thoracic apical vertebra	Before vs. immed after	10.43	<0.001
	Before vs. two years after	9.01	<0.001
	Immed after vs. two years after	−1.43	0.154
Instrumented distal vertebra inclination	Before vs. immed after	10.05	<0.001
	Before vs. two years after	9.40	<0.001
	Immed after vs. two years after	−0.65	0.517

Table 4 – Change in plumb according to the lumbar modifiers of Lenke et al.

Change in plumb	Lenke								p
	A		B		C		Total		
	N	%	n	%	n	%	n	%	
Worsened	1	3.8	3	21.4	0	0.0	4	9.5	0.097
No change	4	15.4	4	28.6	1	50.0	9	21.4	
Improved	21	80.8	7	50.0	1	50.0	29	69.0	
Total	26	100	14	100	2	100	42	100	

Kruskal–Wallis test.

Table 5 – Grading of the changes to the parameters evaluated.

Variable	Description ($n = 42$)
Change to hump	
Worsened	2 (4.8)
Improved 0–25%	6 (14.3)
Improved 25–50%	8 (19)
Improved >50%	26 (61.9)
Change to plumb	
Worsened	4 (9.5)
No change	9 (21.4)
Improved	29 (69)
Change to Cobb (thoracolumbar/lumbar)	
Worsened	1 (2.4)
Improved 0–25%	1 (2.4)
Improved 25–50%	14 (33.3)
Improved >50%	26 (61.9)
Ration main Cobb/thoracolumbar/lumbar Cobb	
> 1	24 (57.1)
Between 1 and 0.5	16 (38.1)
Between 0.5 and 0.25	1 (2.4)
<0.25	1 (2.4)

The relationships of the plumb line and the Cobb TL/L with the last instrumented vertebra are presented in Table 7. In this, it can be seen that the distal level of the arthrodesis (T12 or L10) did not influence the plumb line measurements or the Cobb thoracolumbar/lumbar angle ($p = 0.479$ and $p = 0.194$, respectively).

Discussion

The aims of surgical treatment of adolescent idiopathic scoliosis are to correct the deformity, restore trunk equilibrium and implement arthrodesis on the smallest number of spinal segments possible.[14]

Selective thoracic fusion for avoiding unnecessary fusion of flexible lumbar curves was described by King et al.[1] Several articles have demonstrated a capacity to accommodate lumbar curvature in relation to thoracic curvature, with maintenance of the overall alignment.[14–16] However, in some cases, there may be insufficient accommodation of the lumbar curve and unsatisfactory esthetic results. The prognostic factors for accommodation of the lumbar curvature are not fully established in the current literature.

In the present study, a spontaneous reduction in the Cobb angle of the lumbar curvature of 57% was observed. This value is similar to what was reported by Lenke et al.[14] and was greater than what was described by Parisini et al.[15] (54.8%) and Peelle (50%).[16] However, it was observed two years after the operation that there had been a significant increase in the lumbar Cobb angle ($p = 0.005$). This observation is contrary to previous descriptions, in which the spontaneous lumbar correction was seen to be dynamic and the improvement would occur within the first two years after the surgery.[14,17,18] However, we observed that despite radiographic worsening, no significant clinical deterioration was observed. This can be explained by the fact that there was proportional accommodation of the instrumented TPR curve, which maintained the angular ratio between the curves.

The translation of the instrumented distal vertebra measures the displacement of the spine from the midline. For the lumbar spine, no statistical difference from before to after the surgery was observed. This could have been expected, given that the majority of the curves included were of Lenke type A or B and presented less coronal translation during the preoperative period. Therefore, these presented less potential for surgical correction.

Table 6 – Description of clinical plumb line measurements before and after the operation, in accordance with Lenke et al., and the results from comparative tests.

Variable	Lenke	Mean	SD	Median	Minimum	Maximum	N	p
Plumb before	A	1.52	1.35	1	0	5	26	0.093
	B	0.71	0.87	0.5	0	2.5	14	
	C	1.50	0.71	1.5	1	2	2	
Plumb after	A	0.19	0.43	0	0	2	26	0.604
	B	0.32	0.82	0	0	3	14	
	C	0.50	0.71	0.5	0	1	2	

Table 7 – Comparison between last instrumented vertebra and changes to plumb and Cobb TL/L.

Variable	Arthrodesis level						p
	Finished at L1		Finished at T12		Total		
	N	%	n	%	n	%	
Change to plumb							0.479
Worsened	2	6.2	2	20.0	4	9.6	
No change	5	15.7	1	10.0	6	14.2	
Improved	25	78.1	7	70.0	32	76.2	
Change to thoracolumbar/lumbar Cobb							0.194
Worsened	0	0.0	1	10.0	1	2.3	
Improved 0–25%	1	3.1	0	0.0	1	2.3	
Improved 25–50%	9	28.1	4	40.0	13	31.1	
Improved >50%	22	68.8	5	50.0	27	64.3	
Total	32	100	10	100	42	100	

Mann–Whitney test.

Considering the clinical alterations in relation to the size of the thoracic hump, there was a reduction of approximately 62% after the surgery. Since no thoracoplasty was performed, we attribute the clinical improvement to the capacity for axial correction presented by the surgical technique that was used. However, the correction in this plane was not the aim of the present study and it might be better explained through computed tomography evaluations. Regarding the lumbar hump, although the studies available are limited to those comparing anterior and posterior access routes, the results from the present sample were similar to those of Newton et al.[19] (50%), but were lower than those of Liljenqvist et al.[20] (63%).

Plumb line measurements are an important parameter in surgical treatment for adolescent idiopathic scoliosis.[21] In our study, an improvement in this parameter of 80% was obtained after the operation, which was greater than or similar to what was found by Parisini et al. (52% ± 8.7)[15] and by Liljenqvist et al.[20] (77.7%). However, there were four cases in which there was a worsening of the coronal equilibrium of the trunk. Two of these patients presented associated worsening of the thoracic hump. Among the cases in which there was clinical worsening, three were classified as having lumbar B modifier.

As previously described by Lenke et al.[22] and King et al.,[1] choosing a stable vertebra as the distal fusion level provided trunk equilibrium in most cases. In addition, no clinical or radiographic differences were observed between patients for whom the instrumented distal vertebra was T12 and those for whom it was L1.

According to Bridwell et al.,[23] the derotation maneuver may evolve toward decompensation of the compensatory curves. This is generally caused by overcorrection of the TPR and incapacity for lumbar accommodation. It can be explained by the fact that curves with lumbar type B modifier sometimes have behavior similar to that of type C,[14] which may not be recognized before the operation.

The strong points of the present study were that it had a prospective design and that a homogenous group of Lenke 1 patients was selected. However, the fact that most of the patients analyzed were classified as having lumbar A modifier, and much smaller numbers had subtype B and especially subtype C, can be considered to be a limitation.

Conclusion

1. Arthrodesis performed solely on the main thoracic curvature in Lenke 1 patients provided spontaneous correction of the lumbar curvature and consequent coronal equilibrium of the trunk.
2. The least satisfactory results were observed in cases with lumbar B modifier and these may have been related to overcorrection of the main thoracic curvature.

Conflicts of interest

The authors declare no conflicts of interest.

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