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EFFECT OF SURGICAL TREATMENT OF SCOLIOTIC CURVATURE ON THE SPINE AND UPPER LIMBS

EFEITO DO TRATAMENTO CIRÚRGICO DA CURVATURA ESCOLIÓTICA SOBRE A COLUNA E MEMBROS SUPERIORES

EFECTO DEL TRATAMIENTO QUIRÚRGICO DE LA CURVATURA ESCOLIÓTICA EN LA COLUMNA Y EXTREMIDADES SUPERIORES

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ABSTRACT

Objectives: Evaluate the surgical treatment of scoliotic curvature effects and sagittal radiographic parameters of the spine and upper limbs after surgical treatment with direct vertebral rotation (DVR) associated with type 1 osteotomy in adolescents with idiopathic scoliosis (AIS). Material and Methods: 41 patients with AIS were evaluated and compared before and after surgery. Scoliosis was confirmed by a radiographic of the spine. The radiographic parameters evaluated were: Cobb angles (proximal and distal thoracic), segmental kyphosis (T5-T12), total kyphosis (T1-T12), cervical lordosis (C2-C7), distance from the center of gravity of the skull to C7 (Cervical VAS), measurement of T1 slope (T1), neck slope, IT slope (AP), angle of the upper chest opening and plumb line C7-S1 (SVA C7-S1). Statistical analysis compared the pre- and post-surgical effects of sagittal cervical and shoulder parameters. Results: After the surgical procedure, significant reductions were observed for the following parameters of spine measurement: proximal and distal thoracic Cobb angle, with a correction of 68% of the main thoracic curve. The measurements of the inclination of the T1 profile and the inclination of the neck also improve after surgery. Regarding the shoulders, there was a reduction in T1 AP slope and intercoracoid angle after surgery. The other radiographic parameters did not show significant differences. Conclusion: Surgical treatment with direct vertebral rotation (DVR) associated with type 1 osteotomy promoted better sagittal radiographic parameters of the thoracic Cobb angles, T1 inclination of the cervical spine, neck inclination, and better shoulder symmetry. ***Level of Evidence II; Prospective study***.

Keywords: Shoulder; Surgery; Spine.

RESUMO

Objetivos: Avaliar o efeito do tratamento cirúrgico da curvatura escoliótica, dos parâmetros radiográficos sagitais da coluna e membros superiores após tratamento cirúrgico com rotação vertebral direta (DVR) associada a osteotomia tipo 1 de adolescentes com escoliose idiopática (AIS). Material e Métodos: 41 pacientes com AIS foram avaliados e comparados pré e pós-cirurgia. A escoliose foi confirmada por exame de radiografia da coluna. Os parâmetros radiográficos avaliados foram: ângulos de Cobb (torácico proximal e distal), cifose segmentar (T5-T12), cifose total (T1-T12), lordose cervical (C2-C7), distância do centro de gravidade do crânio até C7 (SVA cervical), medida da inclinação de T1 (T1), inclinação do pescoço, inclinação de TI (AP), ângulo da abertura superior do tórax e linha de prumo C7-S1 (SVA C7-S1). Análise estatística comparando o efeito pré e pós-cirúrgico dos parâmetros sagitais da cervical e ombro. Resultados: Após procedimento cirúrgico observou-se reduções significativas para os seguintes parâmetros de medida da coluna: ângulo de Cobb torácico proximal e distal, com correção de 68% da curva torácica principal. As medidas da inclinação de T1 perfil e da inclinação do pescoço também melhoraram após cirurgia. Com relação aos ombros houve uma redução da inclinação de T1 AP e do ângulo intercoracóideo após cirurgia. Os demais parâmetros radiográficos não apresentaram diferenças significantes. Conclusão: O tratamento cirúrgico com rotação vertebral direta (DVR) associada a osteotomia tipo 1 promoveu melhoria nos parâmetros radiográficos sagitais dos ângulos de Cobb torácica, inclinação de T1 da coluna cervical, inclinação do pescoço e uma melhor simetria dos ombros. ***Nível de evidência II; Estudo prospectivo.***

Descritores: *Ombro; Cirurgia; Coluna Vertebral.*

RESUMEN

Objetivos: Evaluar el efecto del tratamiento quirúrgico de la curvatura escoliótica, parámetros radiográficos sagitales de columna y miembros superiores después del tratamiento quirúrgico con rotación vertebral directa (DVR) asociada a osteotomía tipo 1 en adolescentes con escoliosis idiopática (AIS). Material y métodos: Se evaluaron 41 AIS antes y después de la cirugía. La escoliosis se confirmó un examen radiográfico. Los parámetros evaluados fueron: ángulos de Cobb (torácico proximal y distal), cifosis segmentaria (T5-T12), cifosis

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total (T1-T12), lordosis cervical (C2-C7), distancia del centro de gravedad del cráneo a C7 (VAS cervical), medición de la pendiente T1 (T1), la pendiente del cuello, la pendiente IT (AP), el ángulo de la abertura superior del pecho y la plomada C7-S1 (SVA C7-S1). El análisis estadístico fue para comparar el efecto pre y posquirúrgico. Resultados: Después de cirugía, se observaron reducciones significativas para los siguientes parámetros de medición de la columna: ángulo de Cobb torácico proximal y distal, con corrección del 68% de la curva torácica principal. Las medidas de la inclinación del perfil T1 y la inclinación del cuello también mejoraron después de la cirugía. En cuanto a los hombros, hubo una reducción de la pendiente T1 AP y del ángulo intercoracoideo después de la cirugía. Los demás parámetros radiográficos no mostraron diferencias significativas. Conclusión: El tratamiento quirúrgico con rotación vertebral directa (DVR) asociado a la osteotomía tipo 1 promovió mejores parámetros radiográficos sagitales de los ángulos de Cobb torácicos, inclinación T1 de la columna cervical, inclinación del cuello y mejor simetría del hombro. ***Nivel de Evidencia II; Estudio prospectivo.***

Descriptores: *Hombro; Cirugía; Columna Vertebral.*

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is a three-dimensional spine deformity affecting about 3% of adolescents aged 10-17 years,[1,2] and is the most prevalent type of idiopathic scoliosis.[2,3] Prevalence is higher in females and can reach a 9:1 sex ratio, according to the progression of Cobb's angle above 40 degrees.[4]

In patients with AIS, the increase in Cobb angle above 50 degrees, surgical treatment has been directly indicated, the purpose of which is to contain the progression of the scoliotic curvature and improve the radiographic parameters of the sagittal and coronal planes.[5,6] In the literature, studies have used segmental pedicle screws with spinal derotation maneuver in most scoliosis surgeries in the last two decades.[7-10] During the surgical correction of adolescent scoliosis, direct vertebral derotation (DVD), combined with rod derotation after pedicle screw instrumentation, allows correction of rotational vertebral body deformity, achieving a sufficient correction angle with a sufficient correction angle a reduced fusion level, minimizing aggravated deformity and growth complications.[10,11] Direct vertebral derotation (DVD) is a surgical procedure to correct rotational vertebral body deformity, achieving a sufficient correction angle with a reduced fusion level by instrumentation of the pedicle screw to minimize aggravated deformity and complications due to patient growth.[8-10] The direction of rod derotation (clockwise rotation) should be opposite to that of DVR (counterclockwise rotation) in the apical and periapical vertebrae of the right thoracic curve.[10] The direction of DVR in the lowest instrumented vertebra (LIV) and its effect on the uninstrumented curve are still undetermined.[10,11]

In the late 1990s, the literature showed the use of the new method: DVD designed to promote rotational correction.[7,10-12] The choice of an inappropriate fusion level can result in overcorrection or overcorrection of the major and compensatory curves, which can cause serious problems, such as imbalance and decompensation of the trunk and cervical spine.[13] However, some authors have shown that these techniques do not achieve the same success in correcting the sagittal plane, which is generally associated with worsening thoracic kyphosis.[9,10] The importance of the sagittal plane in improving scoliotic curvature and the complex mechanism of interaction between the curvatures of the spine in its different regions are increasingly important for the postural reorganization of the patient with AIS.[10,14]

Scientific evidence has shown that in patients undergoing traditional surgical treatment of scoliosis, changes in the global and regional alignment of the thoracolumbar and cervical segments are interconnected and that, therefore, correction of the deformity in the coronal and sagittal plane in patients with AIS impacts on postoperative cervical alignment. However, the cervical parameters are not understood after surgical treatment, especially by the DVD technique. Thus, the present study uses the direct vertebral rotation technique to evaluate the sagittal parameters of the cervical spine and shoulder alignment after surgical treatment of adolescent idiopathic scoliosis.

MATERIAL AND METHODS

A cross-sectional observational study was conducted with 43 volunteers with AIS, who were evaluated before surgery (one day before) and after surgery (one month after). Recruitment was conducted through the Public Hospital of the State of São Paulo/SP, Brazil, between January 2018 and December 2019. The study was reviewed and approved by the Research Ethics Committee under number 533756, by the ethical regulations of the Declaration of Helsinki. All the patients evaluated provided the Informed Consent Form about the radiographic evaluations.

The eligibility criteria were: patients aged 15-20 years, male and female, with radiographically confirmed AIS of the distal thoracic curvature (Lenke 1- 6) and Cobb angle between 35 and 55 degrees. The exclusion criteria were: the presence of another spinal deformity or pathology besides AIS, orthopedic pathologies in the hip, pelvis, or lower limbs; the presence of other musculoskeletal disorders such as neuropathies, obesity, rheumatoid arthritis, and/or back pain for more than three consecutive months; the presence of prostheses and/or orthoses in the lower limbs.

Radiographic evaluations: panoramic radiographs

For biplane radiography, i.e., two-dimensional radiography, all patients underwent X-ray imaging in the sagittal profile of the spine as part of the medical request for follow-up and confirmation of the clinical diagnosis of AIS (Figure 1). For the X-ray examination, the patients remained standing with body weight support. The patients' feet remained in the same alignment in the frontal plane, being at a distance of 7.5 cm between them. In the lateral view, the adolescents remained with arms crossed and fingers resting on the clavicles to reduce artifacts due to the projection of the humerus over the spine. All images were focused on the spine and performed by a technician experienced in radiographic examinations. The X-ray images were scanned and transferred to a computer as digital images and evaluated by the attending physician using Surgimap Spine imaging software (Nemaris Inc., New York, USA).[7,9]

The sagittal spinal alignment parameters measured were: proximal and distal thoracic kyphosis angle (T5-T12, measured by the angle form between the upper vertebral plateau of T5 and the lower vertebral plateau of T12),[10-12] the cervical lordosis (C2-C7, measured by Cobb's angle with the perpendiculars between the upper plateau of C2 and the lower plateau of C7), the distance from the center of gravity of the skull to C7 (SVA, measured by the distance between two lines perpendicular to the ground, one drawn at the center of the external cranium-ear and the other at the most posterior point of the upper plateau of C7) T1 profile inclination angle (T1, measured by the angle obtained between the upper plateau of T1 and the ground), neck inclination angle (measured by the angle between two lines starting from the highest point of the sternum, one directed perpendicular to the ground and the other to the center of the upper plateau of T1), and upper chest opening angle (SVA C7-S1, measured by the angle between a line perpendicular to the upper plateau of T1 and a second line drawn in the center of the upper endplate of T1 to the uppermost region of the sternum).[10-12]

For radiographic analysis of shoulder alignment in an anteroposterior (AP) profile, the following measurements were performed: the T1 AP inclination (measured by the angle between a line drawn on the upper plateau of T1 and the ground) and the intercoracoid angle (measured by the angle between the ground and a line drawn between the coracoid processes).[10-12] It is worth noting that the same radiologist always performed the radiographic evaluations to

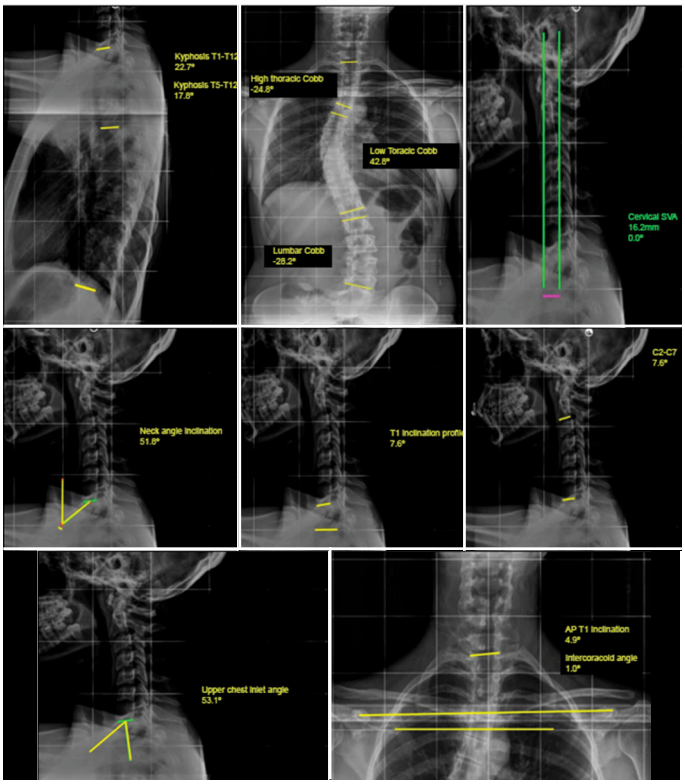

Figure 1. Representation of the radiographic measurements and parameters measured in patients with AIS.

maintain a standard in the radiographs. The images were evaluated one month after the surgical procedure, so the patients were not yet undergoing rehabilitation treatment.

Surgical procedure

The posterior approach with classic midline access was used. After subperiosteal dissection of the musculature, Schwab type 1 osteotomy was performed at all. Still, the most proximal level of arthrodesis and Schwab type 2 osteotomies were performed on periapical vertebrae according to the subjective assessment of curvature reducibility during the procedure. All osteotomies were performed with a Kerrison drill and forceps. Pedicle screws were used exclusively. The entry and insertion of uniplanar screws into the periapical and polyaxial vertebrae were performed by anatomical parameters. All screws were checked by fluoroscopy, and cobalt-chrome rods were used.[15] After placement of the first hypermolded rod according to the patient's pelvic incidence, the locks were placed through the concave side of the deformity, followed by placement of the second molded rod according to the curvature of the kyphosis planned preoperatively. Then, direct vertebral defeating was performed at all levels (except for neutral vertebrae) in the opposite direction of vertebral rotation. In all cases, a suction drain was used, which was removed only at hospital discharge. The patients were encouraged to move early, and no orthoses were prescribed postoperatively.[15]

Statistical Analysis

The sample size of 43 patients was calculated based on the mean preoperative Cobb angle using the G-Power 3.0 software. A moderate effect size (f=0.25), a power of 80%, and a significance level of 5% were used in the calculation**.** The Shapiro-Wilk test tested the normality of the data. Afterward, the radiographic parameters were compared pre- and post-surgery using the paired Student t-test, considering a $p<0.05$. In addition, Cohen's Test effect size calculation was also used, for which values of 0.2, 0.5, and 0.8 were considered to be small, medium, and large effects of surgical treatment, respectively. The tests used *SPSS1TM software* (Version 14.0; SPSS Inc. Chicago, IL, USA).

RESULTS

Of the 43 volunteers with AIS assessed, 15 were male and 28 female, with a Cobb angle of 51.5°± 13.7°, which were compared regarding demographic characteristics, pre- and postoperatively, which showed no statistical differences for any of the variables (p> 0.05), as observed in Table 1.

Table 2 shows the means and standard deviations for all participants' pre- and postoperative radiographic measurements. The results show significant postoperatively reductions for the following spine measurement parameters: proximal thoracic Cobb angle (p = 0.003); distal thoracic Cobb angle (p = 0.001). These reductions showed the effectiveness of surgical correction in reducing Cobb angles and thoracic kyphosis. The DVR surgical technique associated with an osteotomy showed a 68% correction of the main thoracic curve (Figure 1, Table 2).

Another important result was the differences observed in the postoperative period for the radiographic parameters of T1 profile slope measurement (p = 0.013) and neck slope (p = 0.010). Regarding the shoulders, there was a reduction in the values after the surgical procedure, corresponding to an improvement in shoulder symmetry, as verified by the differences in T1 AP inclination (p = 0.012) and intercoracoid angle (p = 0.001). The other parameters: cervical lordosis (C2-C7), the distance from the center of gravity of the skull to C7 (Cervical VAS), and the angle of the upper chest opening and plumb line C7-S1 (C7-S1 VAS) showed no significant differences pre- and postoperatively (Figure 1, Table 2).

DISCUSSION

In this study, using the DVR surgical technique associated with an osteotomy to correct scoliotic curvature in adolescents, it was possible to observe a 68% correction of the main thoracic curve in the coronal plane, with a positive and significant improvement. A similar finding was observed by Urbanski et al.,[15] in which the authors evaluated 21 patients who underwent the DVD surgical procedure and observed a 69% correction of the main thoracic curves. Despite the technique's effectiveness, there is still a divergence

Table 1. Demographic characteristics between groups: preoperative and postoperative of patients with AIS.

Anthropometry	Preoperative	Postoperative	p
Age (years)	17.8 ± 7.1	18.3 ± 6.4	0.342
Height (m)	157.6 ± 8.0	158.6 ± 7.5	0.227
Body weight (kg)	53.5 ± 5.8	54.3 ± 6.2	0.652
Risser (sign)	3.9 ± 1.0	4.1 ± 1.1	0.267

* Based on Student's t-test-dependent measures (pre- and post-surgery), considering differences of $p < 0.05$ as significant.

Table 2. Parameters of the cervical spine and shoulder alignment measured by X-ray in the comparison between groups: preoperative and postoperative and effect size of patients with AIS.

Column Parameters	Pre operative	Post operative	Effect Size	p
Proximal thoracic Cobb angle (degrees)	20.7 ± 9.1	11.9 ± 6.6	1.2	0.003*
Thoracic Cobb angle distall (degrees)	51.3 ± 14.9	16.5 ± 7.5	2.8	0.001*
Cervical lordosis (C2-C7) (degrees)	8.0 ± 2.5	9.2 ± 2.9	0.4	0.378
SVA cervical (cm)	20.1 ± 9.6	21.6 ± 9.9	0.1	0.159
Tilt of T1 profile (degrees)	21.3 ± 8.4	25.2 ± 8.2	0.4	0.013*
Neck inclination (degrees)	38.4 ± 11.4	36.8 ± 12.3	0.2	0.001*
VAS C7-S1 (degrees)	13.9 ± 6.5	16.0 ± 8.1	0.3	0.306
T1 AP tilt (degrees)	1.5 ± 0.6	0.60 ± 0.2	2.0	0.012*
Intercoracoid angle (degrees)	2.4 ± 0.3	0.20 ± 0.1	2.5	0.001*

* Based on Student's t-test-dependent measures (pre- and post-surgery), considering differences of $p < 0.05$ as significant.

among the studies, mainly regarding the standardization of the sample, the surgical correction technique and the fixation materials used, and the standardized surgery time for the evaluations. These points leave difficult comparisons with the literature regarding post-surgical outcomes with the DVD technique, especially considering cervical spine parameters and shoulder alignment.

Currently, the literature is showing an increased interest by researchers in the possible adjustments of the cervical spine and shoulder after surgical treatment of adolescents with idiopathic scoliosis. One of the explanations may be based on studies that observed adjustments of the cervical spine as a function of the progression of scoliotic curvature in the adolescents evaluated.[16,17] In this context, other scientific evidence observed an association between thoracic kyphosis and alignment of the cervical spine, showing that the development of a hypokyphosis in the thoracic spine resulted in a decrease in lordosis of the cervical spine.[17] In this study, an effective correction of the curvatures of thoracic kyphosis can be observed after surgical treatment, but without significant modification of the lordosis of the cervical spine of adolescents with scoliosis. According to Lima et al.,[18] a reduction in sagittal cervical balance is observed in patients with idiopathic scoliosis, with a decrease in cervical lordosis; perhaps this reduction already maintained pre-surgically did not allow for differences after surgery with the DVR technique.

Another finding observed in this study was the adjustment of the alignment of the T1 profile slope and the reduction of the neck slope after the surgical procedure, as well as the improved symmetry of the shoulders verified by the reduction of the T1 AP slope and the intercoracoid angle after the surgical procedure with the DVD technique. According to Shimizu et al.,[19] a better adjustment of T1 slope is observed after increasing or correcting global thoracic kyphosis, corroborating the findings of Pepke et al.[20] in a recent study. However, it is worth noting the improvement in T1 profile and AP inclination, as well as the intercoracoid angle with the DVD technique, which may predict a possible positive adaptation of the cervical region throughout the postoperative period. This fact was also reported by Charles et al.,[21] who found an association between proximal thoracic kyphosis and improvement in T1 profile and cervical lordosis in adolescents with scoliosis.

According to some authors, the improvement of shoulder asymmetry after corrective surgery in patients with scoliosis depends on the amount of correction of the proximal and distal thoracic scoliotic curvature to avoid decompensation of shoulder and cervical spine alignment,[22-25] as previously observed in this study about the improvement of shoulder alignment and some sagittal parameters of the cervical spine. The limitation of this study was the number of patients with hypokyphotic AIS associated with shoulder and cervical spine alignment; however, this was the first study to understand the cervical spine parameters and shoulder alignment after surgical reduction with the en bloc vertebral defeat and direct vertebral defeat technique.

CONCLUSION

Surgical treatment with direct vertebral rotation (DVR) associated with type 1 osteotomy promoted reduction of the scoliotic curvature, with better adjustment of the symmetry of the sagittal radiographic parameters of the angles of the cervical, thoracic, and lumbar spine, as well as adjustment of the T1 tilt of the cervical spine and reduction of the neck tilt favoring shoulder symmetry.

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