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DEFORMITIES

COMPARISON BETWEEN RADIOGRAPHIC METHODS OF MEASURING FLEXIBILITY IN SCOLIOSIS

COMPARAÇÃO ENTRE MÉTODOS RADIOGRÁFICOS PARA MEDIR A FLEXIBILIDADE NA ESCOLIOSE

COMPARACIÓN ENTRE MÉTODOS RADIOGRÁFICOS PARA MEDIR LA FLEXIBILIDAD EN LA ESCOLIOSIS

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ABSTRACT

Objective: To determine the preoperative radiographic method for measuring the Cobb angle that is closest to the postoperative result in patients with scoliotic deformity. Method: Retrospective cohort study of radiographic spinal evaluation (preoperative posteroanterior (PA), bending, traction, traction under anesthesia and immediate postoperative posteroanterior (PO)) of 26 patients treated surgically for scoliotic deformities during the period from January 2017 to September 2019. The final mean Cobb angle and its decrease in relation to the PA value were evaluated in the three curves in patients with idiopathic (IS) and non-idiopathic scoliosis. Results: All the mean curve values were statistically significant, except for bending in non-idiopathic scoliosis (non-IS). The mean traction under anesthesia values were closer to the PO values. Regarding the delta (decrease) of the maneuvers in relation to the PA, no statistical significance was observed in the non-IS group. The traction under anesthesia maneuver had a greater delta in all curves. Conclusion: The traction under anesthesia maneuver in patients with idiopathic scoliosis is the method with the greatest flexibility and which best predicts the postoperative result. ***Level of evidence III; Diagnostic study.***

Keywords: Scoliosis; Radiography; Arthrodesis; Traction; Spine.

RESUMO

Objetivo: Determinar o método radiográfico pré-operatório para aferição do ângulo de Cobb que mais se aproxima dos resultados pós-operatórios em pacientes com deformidade escoliótica. Métodos: Estudo de coorte retrospectivo de avaliação radiográfica da coluna vertebral (posteroanterior pré-operatória [PA], inclinações, tração, tração com anestesia e posteroanterior pós-operatória imediata [PO]) de 26 pacientes com deformidades escolióticas no período de Janeiro de 2017 a Setembro de 2019 tratados com cirurgia . Avaliou-se a média final do ângulo de Cobb e a sua diminuição com relação ao PA nas três curvas em pacientes com escoliose idiopática (EI) e não idiopática. Resultados: Todas as médias das curvas têm significância estatística, exceto a inclinação na escoliose não idiopática (não EI). A tração com anestesia apresenta média de valores mais próximos ao PO. Com relação ao delta (diminuição) das manobras referentes ao PA, foi observado que não houve significância estatística nas não EI. A manobra de tração com anestesia tem delta maior em todas as curvas. Conclusões: A manobra de tração com anestesia em pacientes com escoliose idiopática configura-se como o método com maior flexibilidade e que melhor prediz o resultado pós-operatório. ***Nível de evidência III; Estudo diagnóstico.***

Descritores: *Escoliose; Radiografia; Artrodese; Tração; Coluna Vertebral.*

RESUMEN

Objetivo: Determinar el método radiográfico preoperatorio para medición del ángulo de Cobb que más se aproxima a los resultados postoperatorios en pacientes con deformidad escoliótica. Métodos: Estudio de cohorte retrospectivo de evaluación radiográfica de la columna vertebral (posteroanterior preoperatoria (PA), inclinaciones, tracción, tracción con anestesia y posteroanterior postoperatoria inmediata (PO)) de 26 pacientes con deformidades escolióticas en el período de enero de 2017 a septiembre de 2019 tratados con cirugía. Se evaluó el promedio final del ángulo de Cobb y su disminución con relación al PA en las tres curvas en pacientes con escoliosis idiopática (EI) y no idiopática. Resultados: Todos los promedios de las curvas tienen significancia estadística, excepto la inclinación en la escoliosis no idiopática (no EI). La tracción con anestesia presenta promedio de valores más próximos al PO. Con relación al delta (disminución) de las maniobras referentes al PA, se observó que no hubo significancia estadística en las no EI. La maniobra de tracción con anestesia tiene un delta mayor en todas las curvas. Conclusiones: La maniobra de tracción con anestesia en pacientes con escoliosis idiopática se configura como el método con mayor flexibilidad y que mejor predice el resultado postoperatorio. ***Nivel de evidencia III; Estudio diagnóstico.***

Descriptores: *Escoliosis; Radiografía; Artrodesis; Tracción; Columna Vertebral.*

Study conducted at the Universidade Federal de São Paulo (UNIFESP), São Paulo, SP, Brazil.
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INTRODUCTION

Scoliosis is the most common spinal deformity in children and adolescents. It is defined as a three-dimensional deformity with curvature greater than 10 degrees in the coronal plane, associated with rotation of the vertebral bodies and it can be classified into two large groups: idiopathic and non-idiopathic.[1] The Cobb angle is the main method used to measure the curve, its progression and to define the treatment.[2]

In their classifications, King[3] and Lenke[4] highlighted the importance of the flexibility of the curves in the radiographical examination, formulating the concept of curve structurality and defining it as one of the most important parameters for surgical planning, responsible for the choice of arthrodesis levels and the number of corrective osteotomies.[5-9] Flexibility can be analyzed by several methods: bending in the standing or dorsal horizontal decubitus positions, fulcrum bending, traction, traction under general anesthesia, among others.[5-7,10-12]

Currently, bending radiographs are considered the gold standard for flexibility assessment, because they are easy to perform and are one of the parameters included in the classifications.[5,7,13,14] It is known that in curves greater than 60 degrees traction is better than the other methods.[7,12] More recently, flexibility has begun to be assessed using the traction under anesthesia method. Some studies have demonstrated equivalence with the bending positions, with better correction due to muscle relaxation. However, the fact that it is performed right before surgery is characterized as a disadvantage, not leaving sufficient time for good surgical planning.[14] Nonetheless, there are still no studies that prove which curve flexibility assessment method is closest to the postoperative result.[15]

This study proposes measuring the Cobb angle in standing, bending, traction and traction under anesthesia positions for a comparative analysis of coronal plane flexibility in order to predict the method that most closely matches the postoperative results of patients with scoliosis.

METHODS

This is a retrospective cohort study (level of evidence III). After approval by the Institutional Review Board (C.A.A.E. 25975119.3.0000.5505), which agreed with all the examinations proposed for conducting the project, we reviewed 26 patients (24 females and 2 males) with a mean age of 14.8 years (ranging from 10 to 19 years of age) who underwent surgery to treat scoliotic spinal deformities during the period from January 2017 to September 2019. All patients with their legal guardians agreed to participate in the study and signed the informed consent form.

All surgeries were performed by the same team (senior surgeon and assistants) using the same material and technique. Pedicle screws by posterior approach were used and Ponte osteotomies (mean of 3.6, ranging from 2 to 5) were performed at the apex of the main curve of the deformity to optimize the flexibilization of the curves, to reduce stress on the screws and rods, and to facilitate the correction. All surgeries were performed safely, without complications.

The study inclusion criteria were all patients with scoliotic deformities greater than 40 degrees, as measured by the Cobb Method, operated on during the period mentioned, with spinal radiographs taken (preoperative posterior-anterior (PA), bending, traction, anesthetized traction and immediate postoperative posterior-anterior (PO)) and who agreed to participate in the study. The exclusion criteria were patients with congenital scoliotic deformity and/or who had not undergone all the radiographic examinations or who did not agree to participate in the study.

Performing all the radiographic incidences is part of the UNIFESP Spine Group protocol and the images were obtained from a database. The pre- and postoperative radiographs in PA were taken with patients in orthostasis in panoramic form. The radiographs with lateral bending were taken according to the description of Moe and Byrd,[16] positioning the patient in dorsal decubitus and promoting the maximum active lateral spinal flexion possible. The radiographs under traction and traction with anesthesia were performed using a method similar to that proposed by Davis et al.,[6] in which the patient is in the supine position and one assistant applies a leg traction around the ankles and the other applies underarm traction. The radiograph of traction under anesthesia was performed with the patient in the supine position immediately after general anesthesia, before positioning the patient in the prone position. During the radiograph under anesthesia, evoked potential was performed with no disturbance in neuromonitoring.

The Cobb angle values for the 3 curves (proximal thoracic (TP), main thoracic (T) and thoracolumbar/lumbar (L)) were evaluated in all radiographical incidences. The study was divided into 3 groups (the IS group (idiopathic scoliosis), the non-IS group (non-idiopathic) and all patients together) and the mean and absolute values of the curves in all incidences were calculated. The distribution into 3 groups was proposed so we could have both overall and curve-specific analyses. The 3 maneuvers (bending, traction and anesthetized traction) were compared using the non-parametric Wilcoxon with the PO value, evaluating the maneuver closest to the PO result. Finally, the delta of PA (simple mathematic difference) for each maneuver was calculated and then we compared the 3 maneuvers in each of the 3 curve groups using the Friedman test, to determine the maneuver that presented the greatest mean decrease in value.

P values less than 0.05 were considered statistically significant, with a confidence interval of 95%.

RESULTS

Twenty-six patients were selected (24 females and 2 males), with a mean age of 14.8 years, with non-congenital scoliotic deformities (20 IS and 6 non-IS). The patients were classified using Lenke (40% of the cases were Lenke I and 35% were Lenke III) and King (half of the cases were classified as King 2, followed by 20% as King 3) and they underwent posterior approach arthrodesis (performed in 42.3% of the patients from T4 to L4, and in 06 with arthrodesis that did not include the lumbar curve), as shown in Table 1. The mean values of the initial TP, T and L curves were 28.6 degrees, 72.5 degrees and 49.1 degrees, respectively. The means of the TP, T and L curves were evaluated in the bending, traction, and traction under anesthesia maneuvers and PO as shown in Tables 2, 3 and 4. All had statistical significance except bending in the non-IS group. We noticed that all the radiographs in traction under anesthesia have lower mean values than the other two maneuvers, except in the lumbar region in non-IS cases.

The deltas (simple mathematical) of the maneuvers in relation to the PA in all the curves were evaluated. It was observed that there was no significant difference in the non-IS group. And the delta of correction of the traction under anesthesia maneuver was greater in all curves, as shown in Tables 5, 6 and 7.

DISCUSSION

The evaluation of the flexibility of a curve in patients with AIS is essential prior to surgery to determine whether the curve is structured and to select the approach, the surgical technique and the arthrodesis levels.[4] Many methods have been described for curve flexibility evaluation, among them supine lateral bending,[14,17,18] lateral fulcrum bending,[19,20] traction[21,22] and traction under general anesthesia.[6,10] The degree of correction, however, does not depend only on the technique used, but also on various factors, such as age, magnitude of the curve, type of curve and location of the apical vertebra.[15,23] Due to these factors we observed differences in the flexibility of the same curve depending on the technique used, which can interfere with surgical planning. There is still discussion about which is the best method for predicting postoperative results.

Today, supine lateral bending radiography is considered the gold standard for determining flexibility since it is easy to perform

Table 1. Epidemiological patient data.

Patient	Sex	Age at surgery	Type of Scoliosis	PA main curve	Bending	Traction	Traction under anesthesia	PO	Osteotomies	Instrumentation	King	Lenke	Risser
1	F	17	AIS	80	65	63	47	24	4	T4-L4	2	3CN	V
2	F	12	AIS	68	45	44	30	3	3	T4-L4	2	3C+	IV
3	F	16	AIS	60	42	48	25	0	3	T2-T12	5	2AN	V
4	F	17	AIS	96	85	73	48	24	5	T3-L4	2	3B+	V
5	F	16	AIS	70	46	40	25	27	3	T4-L2	3	1B+	V
6	F	16	AIS	52	20	30	18	6	2	T5-T12	3	1AN	V
7	F	19	AIS	60	27	47	31	6	2	T4-L4	2	3BN	V
8	F	14	AIS	58	31	39	20	5	2	T4-T12	2	1B+	V
9	F	18	AIS	56	23	23	18	8	2	T4-T12	3	1BN	V
10	F	15	AIS	42	17	23	18	0	3	T4-L4	2	3CN	V
11	F	18	AIS	70	36	40	32	24	5	T5-L5	1	6C-	V
12	F	13	AIS	102	87	79	60	13	5	T3-L4	2	3C+	IV
13	F	13	AIS	57	33	28	25	11	2	T4-L4	4	1AN	IV
14	F	16	AIS	56	26	30	28	13	3	T5-T12	3	1BN	V
15	F	14	AIS	83	40	30	14	6	4	T3-L4	2	2C+	V
16	F	13	AIS	82	63	60	42	3	4	T3-L2	5	2B+	V
17	F	14	AIS	90	77	79	60	18	5	T4-L4	2	3B+	V
18	F	14	AIS	60	29	34	26	8	2	T5-L3	4	1AN	V
19	F	16	JIS	72	51	62	56	22	3	T4-T12	2	1B+	V
20	F	10	JIS	86	86	74	68	32	5	T4-L4	1	4B-	III
21	M	15	Syndromic (Marfan)	72	44	72	60	21	5	T4-L4	1	6CN	V
22	F	13	Syndromic (Marfan)	94	84	87	50	19	5	T3-L5	2	3CN	IV
23	F	14	Syndromic (Marfan)	112	103	97	69	44	5	T3-L4	2	3A+	V
24	F	14	Syndromic (Marfan)	77	64	50	44	32	4	T4-L4	5	2BN	V
25	M	16	Syndromic (Marfan)	83	59	37	32	38	5	T4-L4	4	1A+	V
26	F	12	Syndromic (Neuromuscular)	76	31	52	33	21	5	T4-L4	3	1B+	IV

Table 2. Comparison of Maneuvers with PA in the TP Curve.

TP Curve		Mean	Median	Standard Deviation	Q1	Q3	N	CI	P-value
IS	PO	3.4	3	3.5	0	5	20	1.5	- x -
	Bending	16.0	8	15.1	5	27	20	6.6	<0.001
	Traction	15.9	9	13.1	6	28	20	5.7	<0.001
	Traction under Anesthesia	11.0	8	9.5	4	15	20	4.2	<0.001
Non IS	PO	10.7	9	4.7	7	14	6	3.7	- x -
	Bending	18.8	12	15.9	9	26	6	12.7	0.104
	Traction	21.2	18	11.3	15	23	6	9.1	0.028
	Traction under Anesthesia	17.8	14	12.7	10	19	6	10.2	0.043
All	PO	5.1	4	4.8	1	8	26	1.9	- x -
	Bending	16.6	9	15.0	5	29	26	5.8	<0.001
	Traction	17.1	14	12.7	7	27	26	4.9	<0.001
	Traction under Anesthesia	12.6	10	10.5	5	17	26	4.0	<0.001

Table 3. Comparison of maneuvers with PA in the T Curve.

T Curve		Mean	Median	Standard Deviation	Q1	Q3	N	CI	P-value
IS	PO	12.3	10	9.4	6	19	20	4.1	- x -
	Bending	47.0	41	22.5	29	64	20	9.8	<0.001
	Traction	47.0	42	19.1	30	62	20	8.4	<0.001
	Traction under Anesthesia	34.4	27	16.4	24	47	20	7.2	<0.001
Non IS	PO	30.5	31	9.6	23	37	6	7.7	- x -
	Bending	65.0	62	25.5	52	79	6	20.4	0.028
	Traction	62.3	54	24.6	51	79	6	19.7	0.046
	Traction under Anesthesia	47.2	47	12.7	39	50	6	10.2	0.046
All	PO	16.5	15	12.1	6	24	26	4.7	- x -
	Bending	51.2	46	23.9	31	65	26	9.2	<0.001
	Traction	50.5	48	21.0	31	63	26	8.1	<0.001
	Traction under Anesthesia	37.3	32	16.3	25	50	26	6.3	<0.001

and used for AIS classification.[4,24] However, recent studies have shown that this technique may not correctly predict the degree of postoperative correction, in addition to being dependent on the patient and on the radiology technique for its execution.[25-27]

Radiographs with traction are less commonly used for preoperative planning. Vaughan et al., Poly and Sturm demonstrated in their studies that traction is superior to bending when curves are greater than 60 degrees.[18,21-23] In our study, we did not observe a statistical difference between the curves of the idiopathic scoliosis group (mean main curve: 71.2º) and the whole group (mean main curve: 72.5º). We noticed that the mean curves with maneuvers, both in the TP (IS: bending 16º, traction 15.9º; All: bending 16.6º, traction 17.1º) and T (IS: bending 47º, traction 47º; All: bending 51.2º, traction 50.5º), had very similar values. These data go against the study of Moe et al., who emphasized the importance of traction as a method for determining the degree of postoperative correction in wide curves.[28] They also differ from the study by White and Panjabi, which showed traction to be inferior for curves less than 53° and superior for larger curves.[29,30] However, in all these studies, including this one, the only variable analyzed was the Cobb angle. As regards the L curve, we noted that bending presented lower values than traction, (Table 3) a finding similar to the

Table 4. Comparison of Maneuvers with PA in the L Curve.

Curve L		Mean	Median	Standard Deviation	Q1	Q3	N	CI	P-value
IS	PO	7.2	5	7.1	1	12	20	3.1	- x -
	Bending	19.4	13	18.3	5	34	20	8.0	0.012
	Traction	29.3	30	16.3	17	41	20	7.2	<0.001
	Traction under Anesthesia	18.1	16	11.1	10	28	20	4.9	<0.001
Non IS	PO	13.0	12	8.7	7	20	6	6.9	- x -
	Bending	29.5	28	13.5	20	42	6	10.8	0.046
	Traction	37.0	28	22.2	21	51	6	17.8	0.028
	Traction under Anesthesia	33.0	26	22.0	18	53	6	17.6	0.028
All	PO	8.5	8	7.7	2	14	26	3.0	- x -
	Bending	21.7	16	17.6	6	36	26	6.8	0.001
	Traction	31.0	30	17.7	17	43	26	6.8	<0.001
	Traction under Anesthesia	21.5	18	15.2	11	30	26	5.9	<0.001

Table 5. Comparison of Delta of Maneuvers in Relation to PA in the TP Curve.

TP Curve		Mean	Median	Standard Deviation	Q1	Q3	N	CI	P-value
IS	Bending	12.0	10	8.3	6	16	20	3.6	0.001
	Traction	12.4	10	8.1	8	20	20	3.6	
	Traction under Anesthesia	17.0	16	10.4	9	24	20	4.5	
Non IS	Bending	12.0	12	2.6	10	14	6	2.1	0.186
	Traction	9.7	10	5.6	7	14	6	4.5	
	Traction under Anesthesia	13.0	13	4.9	12	15	6	3.9	
All	Bending	12.0	11	7.3	7	16	26	2.8	0.001
	Traction	11.8	10	7.6	7	18	26	2.9	
	Traction under Anesthesia	16.0	15	9.5	9	22	26	3.6	

Table 6. Comparison of Delta of Maneuvers in Relation to PA in the T Curve.

T Curve		Mean	Median	Standard Deviation	Q1	Q3	N	CI	P-value
IS	Bending	21.9	22	10.2	16	28	20	4.4	<0.001
	Traction	21.9	22	10.5	14	25	20	4.6	
	Traction under Anesthesia	34.5	34	13.1	28	39	20	5.8	
Non IS	Bending	19.5	15	13.6	11	22	6	10.9	0.311
	Traction	22.2	20	16.2	11	26	6	13.0	
	Traction under Anesthesia	37.3	43	11.8	36	44	6	9.5	
All	Bending	21.3	21	10.8	14	27	26	4.1	<0.001
	Traction	22.0	22	11.7	13	26	26	4.5	
	Traction under Anesthesia	35.1	34	12.7	29	43	26	4.9	

study by Watanabe et al.,[15] which obtained a statistical difference when the initial Cobb angle was less than 50º, as in our study in which the mean L curve found was 49.1º.

In the traction under anesthesia technique described by Davis et al.,[6,8] in which muscle relaxation removes traction discomfort for the patients, a better result was obtained. In this study it was observed that this method had a greater absolute decrease in the mean curve, coinciding with Davis et al. and Hamzaoglu et al.,[10] (Tables 1, 2 and 3) being always less than bending and traction and closer to the postoperative values.

Table 7. Comparison of Delta of Maneuvers in Relation to PA in the L Curve.

L Curve		Mean	Median	Standard Deviation	Q1	Q3	N	CI	P-value
IS	Bending	28.1	28	8.9	24	33	20	3.9	<0.001
	Traction	18.2	16	10.3	11	26	20	4.5	
	Traction under Anesthesia	29.4	31	11.3	24	33	20	5.0	
Non IS	Bending	25.0	25	7.8	19	32	6	6.3	0.186
	Traction	17.5	16	13.1	7	28	6	10.5	
	Traction under Anesthesia	21.5	18	15.7	15	31	6	12.5	
All	Bending	27.3	28	8.6	22	33	26	3.3	<0.001
	Traction	18.0	16	10.8	10	27	26	4.1	
	Traction under Anesthesia	27.5	30	12.6	17	33	26	4.8	

Gotfryd et al., conducted a study in which they evaluated the lateral bending maneuver as a predictive factor for surgical correction in adolescent idiopathic scoliosis. They found that it is possible to predict the percentage of surgical correction of the main thoracic curve. Our study demonstrated that in the patient with the traction under anesthesia maneuver there was both a greater correction delta and a more accurate estimation of the postoperative value. However, there are still no studies that evaluate traction under anesthesia as a predictive factor for scoliotic curve correction.

The literature lacks good studies that evaluate flexibility of non-idiopathic curves. In our study, we had no statistical results in its evaluation due to the small number of patients. Other studies should be conducted to evaluate it.

Our study has some limitations, such as not using the fulcrum bending maneuver, which would offer another point of comparison, as demonstrated in the systematic review published by Khodaei et al.,[5] as the most accurate method for estimating the postoperative Cobb angle. The use of Ponte osteotomies to flexibilize the curve for better postoperative correction due to the high degree of the curves may be a bias. As patient follow-up was only conducted until the immediate postoperative period, it was not possible to assess the spontaneous correction of non-instrumented curves. In addition, we did not compare the density of curve instrumentation with their degree of correction and thus did not identify whether higher-density curves present better correction as compared to the lower density curves.

However, this study will serve as the basis to stimulate further research in an attempt to identify the maneuver that can best predict the immediate postoperative result in the correction of scoliotic deformity.

CONCLUSION

In this study we concluded that traction under anesthesia in patients with idiopathic scoliosis is the method with the most flexibility and the one that best predicts postoperative results. More prospective studies with a greater number of patients, particularly, non-idiopathic patients, should be conducted to validate the findings.

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