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PRE- AND POSTOPERATIVE COMPARATIVE ANALYSIS OF THE SPINOPELVIC AND GLOBAL SAGITTAL PARAMETERS OF PATIENTS WITH ADOLESCENT IDIOPATHIC SCOLIOSIS

ANÁLISE COMPARATIVA PRÉ E PÓS-OPERATÓRIA DOS PARÂMETROS ESPINO-PÉLVICOS E SAGITAL GLOBAL DOS PACIENTES COM ESCOLIOSE IDIOPÁTICA DO ADOLESCENTE

ANÁLISIS COMPARATIVO PRE Y POSTOPERATORIO DE LOS PARÁMETROS ESPINO-PÉLVICOS Y SAGITAL GLOBAL EN PACIENTES CON ESCOLIOSIS IDIOPÁTICA DEL ADOLESCENTE

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ABSTRACT

Objective: To analyze the pre- and postoperative spinopelvic parameters and global sagittal balance of patients with adolescent idiopathic scoliosis (AIS) divided into 3 groups (Group 1 – thoracic arthrodesis, Group 2 - thoracolumbar arthrodesis, and Group 3 – lumbar arthrodesis), observing differences in these two moments and whether the parameter values are maintained or not over a period of up to 2 years following surgery. Methods: We analyzed the radiographs from a single-center database of 99 patients who underwent arthrodesis with posterior instrumentation. Pelvic incidence, pelvic version, sacral slope, lumbar lordosis, thoracic kyphosis, and sagittal vertical axis values were measured in the pre- and postoperative radiographies of each patient. Results: The parameters of pelvic incidence, pelvic version, sacral slope, and sagittal vertical axis did not show statistically significant differences among the 3 groups. There was a difference in preoperative lumbar lordosis between the 3 groups ($p = 0.049$). Thoracic kyphosis showed differences both in the pre- ($p = 0.015$) and postoperative ($p = 0.042$) values, in addition to demonstrating a relationship of dependence between the pre- and postoperative values in the final statistical analysis. Conclusion: The evaluation of the parameters analyzed shows that the study groups have similar values of individual balance, with the exception of thoracic kyphosis and lumbar lordosis, which are measurements that depend on the surgical technique and compensatory mechanisms, but remained within normal ranges. These factors allow the surgeon to be attentive to both the coronal and sagittal planes when planning the correction in order to achieve the equilibrium of the trunk in addition to correction of the deformity. ***Level of Evidence IIIA: Comparative retrospective study.***

Keywords: Scoliosis; Arthrodesis; Kyphosis.

RESUMO

Objetivo: Analisar parâmetros espino-pélvicos e equilíbrio sagital de pacientes com escoliose idiopática do adolescente (EIA) no pré e pós-operatório em três grupos (grupo 1 – artrodese torácica, grupo 2 toracolombar e grupo 3 – artrodese lombar), observando diferenças nesses dois momentos e se os parâmetros são mantidos ou não por um período de até dois anos de pós-operatório. Métodos: Foram avaliadas radiografias de 99 pacientes de um banco de dados de um único centro, que foram submetidos a artrodese por via posterior. Foram aferidos valores da incidência pélvica, versão pélvica, inclinação sacral, lordose lombar, cifose torácica e eixo vertical sagital nas radiografias pré e pós-operatória. Resultados: Os parâmetros de incidência pélvica, versão pélvica, inclinação sacral e do eixo vertical sagital não apresentaram diferenças estatisticamente significantes nos três grupos. A lordose lombar apresentou diferença entre os três grupos no pré-operatório ($p = 0,049$). A cifose torácica apresentou diferenças tanto no pré ($p = 0,015$) quanto no pós-operatório ($p = 0,042$), além de demonstrar relação de dependência nos valores do pré e pós na análise estatística final. Conclusões: A avaliação dos parâmetros analisados mostra que os grupos estudados apresentam valores semelhantes de equilíbrio do indivíduo, com exceção da cifose torácica e lordose lombar que são medidas dependendo da técnica cirúrgica e dos mecanismos compensatórios, porém mantendo-se dentro da faixa normal. Esses fatores permitem ao cirurgião ficar atento no planejamento da correção tanto no plano coronal quanto no plano sagital para conseguir, além da correção da deformidade, o equilíbrio do tronco. ***Nível de Evidência IIIA; Estudo retrospectivo comparativo.***

Descritores: *Escoliose; Artrodese; Cifose.*

RESUMEN

Objetivo: Analizar los parámetros espino-pélvicos y el equilibrio sagital de pacientes con escoliosis idiopática del adolescente (EIA) en el pre y postoperatorio divididos en 3 grupos (grupo 1 - artrodesis torácica, grupo 2 - toracolumbar y grupo 3 - artrodesis lumbar), observando las diferencias en estos dos momentos y si los parámetros se mantienen o no durante un periodo de hasta 2 años en el

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postoperatorio. Métodos: Se evaluaron las radiografías de 99 pacientes de una base de datos de un solo centro, a quienes se les realizó artrodesis por vía posterior. Se midieron los valores de incidencia pélvica, versión pélvica, inclinación sacra, lordosis lumbar, cifosis torácica y eje vertical sagital en las radiografías pre y postoperatorias de cada paciente. Resultados: Los parámetros de incidencia pélvica, versión pélvica, inclinación sacra y eje vertical sagital no presentaron diferencias estadísticamente significativas en los 3 grupos. La lordosis lumbar presentó una diferencia entre los 3 grupos en el preoperatorio (p = 0,049). La cifosis torácica presentó diferencias tanto en el pre (p = 0,015) como en el postoperatorio (p = 0,042), además de presentar una relación de dependencia entre los valores del pre y postoperatorios en el análisis estadístico final. Conclusiones: La evaluación de los parámetros analizados muestra que los grupos estudiados presentan valores de equilibrio individual similares, con excepción de la cifosis torácica y la lordosis lumbar, que se miden en función de la técnica quirúrgica y de los mecanismos compensatorios, pero manteniéndose dentro del rango normal. Estos factores permiten al cirujano estar atento a la hora de planificar la corrección tanto en el plano coronal como en el sagital, para lograr, además de corregir la deformidad, el equilibrio del tronco. ***Nivel de evidencia IIIA; Estudio retrospectivo comparativo.***

Descriptores: *Escoliosis; Artrodesis; Cifosis.*

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is a common and potentially serious musculoskeletal disorder that affects 2 to 3% of the pediatric population. It is classically defined as a curve > 10° in the coronal plane associated with vertebral rotation in the axial plane. It is also known that it is usually associated with a loss of thoracic kyphosis.[1-3] When surgical treatment is indicated, the main objective is to stabilize the deformity and restore the coronal and sagittal balance of the trunk.

Recent studies have sought to clarify the impact of arthrodesis on the spinopelvic and sagittal parameters. Since Duval-Beaupere et al. defined pelvic incidence (PI) in 1992, several studies have shown a strong relationship between this parameter and the lumbar lordosis of patients in orthostasis.[4,5] This association can be represented by the following formula: PI = PV (pelvic version) + SS (sacral slope).[6,7]

Of all the measurements that define overall sagittal alignment and spinopelvic parameters, PI is perhaps the most important since its value tends to be fixed regardless of age or posture.[7] Recent studies have recognized the importance of sagittal balance and spinopelvic alignment in both normal and abnormal situations. Recent studies by Mac-Thiong, Labelle, and Roussouly[8] have shown that there is a strong relationship between pelvic configuration and lumbar lordosis, also corroborated by studies by Upasani, Xi-Ming Xu, and Kerim and Sariyilmaza.[9-11] Parameters such as PI, PV, SS, and SVA (sagittal vertical axis) (Table 1) may undergo modifications that allow the patient to maintain or reestablish sagittal balance, even with changes in the physiological curvatures, such as lumbar lordosis and thoracic kyphosis resulting from surgical intervention.

Sagittal plane deformities, such as the loss of lumbar lordosis, can cause positive trunk balance, affecting sagittal balance. The main causes of loss of sagittal balance are degenerative diseases, iatrogenic fixation of the lumbar spine, post-traumatic deformity, and ankylosing spondylitis. [12] The objective of our study is to relate the segment level of the arthrodesis to the changes or adaptation in these parameters in the AIS population. In addition, poor surgical planning can bring about parameter changes that leave the patient imbalanced. (Figure 1)

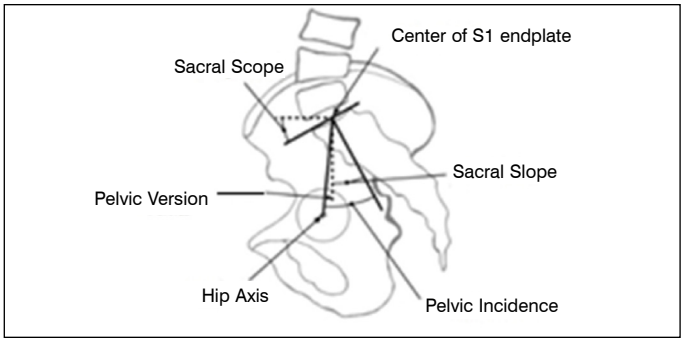

Figure 1. Spinopelvic parameters.

METHODS

This study is a retrospective analysis of radiological images from a single-center database of patients operated between 2012 and 2019. It was approved by the ethics committee of the institution where it was conducted. The radiographic parameters were calculated using validated software (mConnect version 02.001.00). As inclusion criteria, all patients with AIS who underwent surgery between 2012 and 2019 and were between 10 and 18 years of age at the time of surgery were selected (n=125). In the present study, stratification by age groups was not possible because it would establish heterogeneity and not allow division as proposed (by arthrodesis segment level). Exclusion criteria were patients without pre- or postoperative examinations (n=8), unsuitable examinations (low radiographic density, incomplete inclusion of the pelvis and lumbosacral segment, and poor clarity of the spinopelvic parameters) (n=18), age < 10 years, diagnosis other than AIS, and patients requiring surgical revision. A total of 99 patients satisfied the study inclusion criteria. The pre- and postoperative radiographic analysis included lateral orthostatic radiographs, which were evaluated in a standardized process (performed solely by the main author) that measured pelvic incidence, pelvic version, sacral slope, lumbar lordosis, thoracic kyphosis, and the sagittal vertical axis. The postoperative control of the radiographs analyzed in the present study corresponded to a mean interval between 1 and 2 years after the surgery, except for patients operated in 2019 whose control analysis corresponded to less than one year following surgery.

These patients were divided into 3 groups according to the segment with the arthrodesis: thoracic arthrodesis (Group 1) with caudal instrumentation as far as L1, thoracolumbar arthrodesis (Group 2) including from T2 to L4 and their intervals, and lumbar arthrodesis (Group 3) with the most cranial instrumentation in T7 and the most caudal instrumentation in L4 (in addition to their intervals).

RESULTS

There were no statistically significant differences between pre- and postoperative PI, PV, SS, and SVA either within each group or in the comparisons between them. In addition, the physiological values and sagittal balance remained preserved. Table 1 shows the results.

The analysis of lumbar lordosis showed that preoperative values were different among the 3 groups, with Group 2 having the highest mean values. Group3 had the lowest mean postoperative values (Table 2).

Groups 1 and 2 showed a statistically significant difference in preoperative lumbar lordosis. Group 3 had a lower postoperative LL, although not significantly so, as shown in Table 3.

The pre- and postoperative kyphosis results demonstrate a relationship of dependence between the initial and final values. It was verified that the preoperative kyphosis values differed among the groups (Table 4) but became similar in the postoperative period, showing that the surgeon's intended value corresponded to the expectations for correction. During the analysis of the postoperative values no proximal junctional kyphosis was observed.

Table 1. Pre- and postoperative parameter values.

Group 1	**PI**	**PV**	**SS**	**SVA (cm)**
Pre-op	49.5° ± 6.8°	11.2° ± 5.1°	38.5° ± 4.8°	-1.4 ± 2.4
Post-op	49.4° ± 6.8°	12.8° ± 5.5°	36.8° ± 5.2°	-1.7 ± 3.1
P	0.189	0.003	0.004	0.381
Group 2	**PI**	**PV**	**SS**	**SVA (cm)**
Pre-op	51.3° ± 8.4°	10.5° ± 6.2°	40.8° ± 5.9°	-2 ± 2.6
Post-op	51.3° ± 8.4°	11.5° ± 7.2°	39.9° ± 6.6°	-2.4 ± 3
P	0.739	0.106	0.123	0.329
Group 3	**PI**	**PV**	**SS**	**SVA (cm)**
Pre-op	46.7° ± 5.6°	10° ± 5.7°	37° ± 2.9°	-3.1 ± 2.5
Post-op	46.7° ± 5.4°	12.2° ± 5.3°	34.5° ± 5.1°	-2.4 ± 2.2
P	0.906	0.320	0.279	0.290

Table 2. Comparison of lumbar lordosis values.

Group	**n**	**Mean ± Standard Deviation**			**P value***
		Pre-op LL	**Post-op LL**	**Post - pre**	
1	50	56.9 ± 8.1	57.8 ± 8.4	0.9 ± 6.5	0.355
2	42	61.5 ± 10.6	59.8 ± 11.6	-1.7 ± 8.4	0.190
3	7	56.8 ± 4.6	53.2 ± 7.6	-3.6 ± 5.6	0.138

Table 3. Lumbar Lordosis – statistical relevance among the 3 groups.

Groups being compared (preoperative period)	**P value**
Group 1 x Group 2	0.018
Group 1 x Group 3	0.978
Group 2 x Group 3	0.211

Table 4. Comparison of Thoracic Kyphosis among the 3 groups.

Group	**n**	**Mean ± Standard Deviation**			**P value***
		Pre-op TK	**Post-op TK**	**Post - pre**	
1	50	25.3 ± 11.2	35.2 ± 8.5	9.9 ± 7.7	<0.001
2	42	32.7 ± 15.3	35 ± 8.3	2.4 ± 12.6	0.235
3	7	34.9 ± 11.2	36.9 ± 10.1	2.1 ± 7.7	0.506

The Group 1 patients tended to be more hypokyphotic than the other two groups, even though the preoperative mean value of the sample was normokyphotic. And in the postoperative period, all of them presented kyphosis within the physiological range ($p < 0.001$), and the mean postoperative thoracic kyphosis values were similar for all 3 groups (Table 4).

DISCUSSION

Thoracic kyphosis and lumbar lordosis measurements are used to analyze trunk alignment. More recently, with the introduction of the concepts of pelvic incidence (PI), pelvic version (PV), and sacral slope (SS),[12] the role of the pelvis has been widely recognized in the assessment of spinal balance and alignment.[12]

It is known that pelvic incidence (PI) is a constant morphological parameter in the skeletally mature patient, regardless of patient positioning or surgical intervention (S. Ohrt-Nissen et al.).[13] Defining whether PI remains constant following surgery in adolescent idiopathic scoliosis patients is the objective of several studies that, to date, are inconclusive. Mac-Thiong et al.[14] found a mean PI value of 46.9° ± 11.4° in healthy adolescents and, in the study by S. Ohrt-Nissen et al., this value increased by 2° in patients with adolescent idiopathic scoliosis (AIS) following surgery, regardless of the type of curve instrumented. This result is similar to our findings in the group of patients with selective thoracic instrumentation. As these are often skeletally immature patients, they do not conform to the PI constancy ratio expected in mature patients.[15] The comparison of the values of Groups 2 and 3, with thoracolumbar and lumbar instrumentation showed differences, though not statistically relevant ($p = 0.739$ and $p = 0.906$, respectively), but the pre- and postoperative values within the same group were similar, in accordance with the literature.

There is also a close relationship between lumbar lordosis (LL) and pelvic version (PV).[16] A decrease in LL, whether iatrogenic or due to pathological modifications, implies an increase in PV.[17] Two useful equations for determining the appropriate LL have already been introduced: $LL = 0.56\ PI + 33.43$ / $PI = SS + PV$, and $LL = PI + 10$.

The present study demonstrated a non-significant postoperative increase in lumbar lordosis in Group 1, even with the increase in PV ($p = 0.355$). The other two groups respected the mathematical relationship ($LL = 0.56\ PI + 33.43$) of a postoperative decrease in lordosis with an increase in PV. And in a balanced patient following surgery, these small variations in the parameters, which are not directly dependent on the surgeon, are not statistically significant.

The etiology of hypokyphosis associated with the thoracic spine is unknown in most AIS patients, although some postulate that the relative growth of the anterior spine may play a certain role.[18] Dickson et al. suggested that relative thoracic lordosis was the "essential lesion" in thoracic scoliosis,[19] thus also making proper correction of the deformity in the sagittal plane important.

A number of factors related to the surgical technique and associated with the restoration of thoracic kyphosis have been reported, such as greater use of the Ponte osteotomy, choice of material (steel, titanium alloy, cobalt-chromium alloy), segmental pedicle fixation,[20] and rod molding. The magnitude of the curve and its flexibility were considered underlying factors that influence postoperative correction.[21,22]

Rod molding, together with spinal fixation, influences the pelvic parameters.[23,24]

The objective of our study was to evaluate pre- and postoperative parameters to determine whether the normal spinopelvic parameter and sagittal balance values were maintained. Comparing the mean variation in kyphosis became relevant, since there was a great variation in the range of the variable in both the pre- (6.6° - 86.2°) and postoperative (18.2° - 59.7°) periods; and, consequently, so did determining what type of influence this variation has on overall sagittal alignment with each group and in the comparison among them. Thus, despite this variation, the postoperative data in the 3 groups indicated the maintenance of normal parameter values and the presence of a sagittally-balanced individual.

Our study had the following limitations: 1) The inferior quality of some radiographs interfered with the measurement of the study parameters, which could have impacted some results, but we were able to match our values against those in the literature. 2) The sample, particularly in Group 3, was small. 3) There are no studies with significant samples that reported normal spinopelvic parameter values in the study population. 4) No PA radiographs were analyzed to determine whether the degree of deformity correction in the coronal plane influenced modification of the parameters studied. 5) Even considering that PI tends to present a fixed postoperative value in the skeletally mature patient, there are no consistent studies that prove the veracity of such a statement in patients with AIS, mainly because this population varies widely between skeletally mature and immature individuals, therefore requiring a division into groups based on a skeletal maturity classification protocol, such as that of Sanders. 6) Acetabular/pelvic orientation (anteversion or retroversion), an important parameter in the determination of some spinopelvic parameters, was disregarded in our analysis. 7) The patients operated in 2019 had no radiographic control 1 year after surgery, a fact that does not allow us to say whether the parameters evaluated changed during the minimal follow-up period.

CONCLUSION

The pre- and postoperative evaluations of patients with AIS through an analysis of spinopelvic and overall sagittal parameters showed us that the study groups had no statistically significant differences from their normal values. There were differences in the LL values between Groups 1 and 2, though not statistically significant. Therefore, thoracic kyphosis was the only parameter that

presented statistically significant differences, demonstrating that the correction and rod molding maneuvers, as well as the osteotomies, are determinants for the maintenance of the patient's physiological curvatures and normal spinopelvic parameter values. Even so, their values remained within the physiological range in most cases, and in patients who had relative thoracic lordosis, adequate correction to normal values was demonstrated in the postoperative period. This information allows us to conclude that in addition to the calculation of the Cobb angles to define the types of scoliosis and determine their corrections, we must analyze the spinopelvic and sagittal parameters for maintenance or correction of trunk balance, both in the coronal and sagittal planes.

The nature of the study, conducted at a single center, limits is external validity. For this reason, further multiple-center studies are necessary to identify factors that influence the interdependence of spinopelvic parameters in the population studied.

All authors declare no potential conflict of interest related to this article.

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