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SAGITTAL MISALIGNMENT IN ADOLESCENT IDIOPATHIC SCOLIOSIS

DESALINHAMENTO SAGITAL NA ESCOLIOSE IDIOPÁTICA DO ADOLESCENTE

MALA ALINEACIÓN SAGITAL EN LA ESCOLIOSIS IDIOPÁTICA DEL ADOLESCENTE

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ABSTRACT

Introduction: The correlation between sagittal and coronal parameters in patients with adolescent idiopathic scoliosis (AIS) presents contradictory results and is not fully understood. Objective: To evaluate the sagittal vertical axis (SVA) and its correlation with sagittal parameters and the main curve in patients diagnosed with AIS. Methods: 109 patients with AIS and indications for surgical treatment were evaluated. The correlation of the SVA with sagittal parameters (thoracic kyphosis, lumbar lordosis, pelvic incidence, lumbar lordosis, pelvic version, and sacral inclination) and with the main curves (main thoracic and thoracolumbar/lumbar) was evaluated. Results: The SVA ranged from -208 to 66.30 mm (mean -19.64 ± 36.21), above 50 mm in two patients (1.83%). There was no correlation between the sagittal parameters and the magnitude of the main curve and the SVA. Conclusion: The SVA showed great variability in the group of patients with AIS; a small percentage of patients had an SVA greater than 50 mm. The low percentage of patients with sagittal misalignment showed the compensatory capacity of young patients with vertebral deformity. ***Level of Evidence: III; Observational and Retrospective Study.***

Keywords: Scoliosis; Adolescent; Lordosis; Kyphosis.

RESUMO

Introdução: A correlação entre os parâmetros sagitais e coronais nos pacientes com escoliose idiopática do adolescente (EIA) apresenta resultados contraditórios e não está totalmente esclarecida. Objetivo: Avaliar o eixo sagital vertical (SVA) e sua correlação com parâmetros sagitais e a curva principal de pacientes com diagnóstico de EIA. Métodos: Foram avaliados 109 pacientes com EIA e indicação de tratamento cirúrgico. Foi avaliada a correlação do SVA com parâmetros sagitais (cifose torácica, lordose lombar, incidência pélvica, lordose lombar, versão pélvica e inclinação do sacro) e com as curvas principais (torácica principal e toracolombar/lombar). Resultados: O SVA variou de -208 a 66,30 mm (média -19,64 ± 36,21), ficando acima de 50 mm em dois pacientes (1,83%). Não foi observada correlação dos parâmetros sagitais e da magnitude da curva principal com o SVA. Conclusão: O SVA apresentou grande variabilidade no grupo de pacientes com EIA e pequena porcentagem dos pacientes apresentaram SVA maior que 50 mm. A baixa porcentagem de pacientes com desalinhamento sagital evidenciou a capacidade compensatória dos pacientes jovens e com deformidade vertebral. ***Nível de Evidência: III; Estudo Observacional e Retrospectivo.***

Descritores: *Escoliose; Adolescente; Lordose; Cifose.*

RESUMEN

Introducción: La correlación entre los parámetros sagitales y coronales en pacientes con escoliosis idiopática del adolescente (EIA) presenta resultados contradictorios y no se comprende completamente. Objetivo: Evaluar el eje vertical sagital (SVA) y su correlación con los parámetros sagitales y la curva principal en pacientes diagnosticados de EIA. Métodos: Se evaluaron 109 pacientes con EIA e indicación de tratamiento quirúrgico. Se evaluó la correlación del SVA con parámetros sagitales (cifosis torácica, lordosis lumbar, incidencia pélvica, lordosis lumbar, versión pélvica e inclinación sacra) y con las curvas principales (torácica principal y toracolumbar/lumbar). Resultados: El SVA osciló entre -208 y 66,30 mm (media -19,64 ± 36,21), siendo superior a 50 mm en dos pacientes (1,83%). No hubo correlación entre los parámetros sagitales o la magnitud de la curva principal y el SVA. Conclusión: El SVA mostró una gran variabilidad en el grupo de pacientes con EIA y un pequeño porcentaje de pacientes presentó una SVA superior a 50 mm. El bajo porcentaje de pacientes con desalineación sagital mostró la capacidad compensatoria de los pacientes jóvenes con deformidad vertebral. ***Nivel de Evidencia: III; Estudio Observacional y Retrospectivo.***

Descriptores: *Escoliosis; Adolescente; Lordosis; Cifosis.*

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INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is a three-dimensional deformity of the vertebral column (lateral, sagittal, and rotational deviation), and its deviations are coupled.[1,2] However, the relationship between deviations in the coronal plane, sagittal plane, and vertebral alignment in patients with AIS is not fully clarified, and there are contradictory reports in the literature.[3-5] The type of curve in the coronal plane and its magnitude are apparently unrelated to sagittal parameters.[5]

Global spinal alignment is an important parameter in assessing patients with spinal deformity. This alignment is the result of the interaction of the kyphotic and lordotic curves of the vertebral column with the pelvis and evaluated through the horizontal displacement of the center of C7 to the back edge of S1. The assessment of this measurement in profile radiographs of the spine is called the sagittal vertical axis (SVA).[6] (Figure 1)

The back edge of the sacrum is the anatomical reference for the measurement of SVA. The SVA is considered positive when the previous displacement of C7 over S1 occurs and negative when it comes later. In normal individuals, the SVA is generally neutral or slightly positive, and a value of 5 cm is considered the normal limit. In adolescents, the SVA has shown neutral or slightly positive values, with profile radiographs performed with the upper limbs next to the trunk and the subsequent displacement of the SVA with the upper limbs in flexion.[7]

The study's objective was to assess the prevalence of sagittal spinal misalignment in patients with AIS who were indicated for surgical treatment and its correlation with sagittal spinal parameters.

METHODS

The Institutional Research Ethics Committee (IREC) approved the study: 39839820.2.0000.5273). An observational and retrospective study involved 109 patients diagnosed with AIS and indicated for surgical treatment.

Panoramic radiographs of the vertebral column were performed in the orthostatic anteroposterior (AP) position and profile. In the profile position, the upper limbs were supported on support in the flexion position, with the patients in the relaxed position and the hips and knees extended. The radiographic images were digitized and inserted into the DICOM (Digital Imaging and Communications in Medicine) system. The parameters selected for the study were measured using the Surgimap Spine software (Nemaris Inc. New York, USA, version 2.2.13).

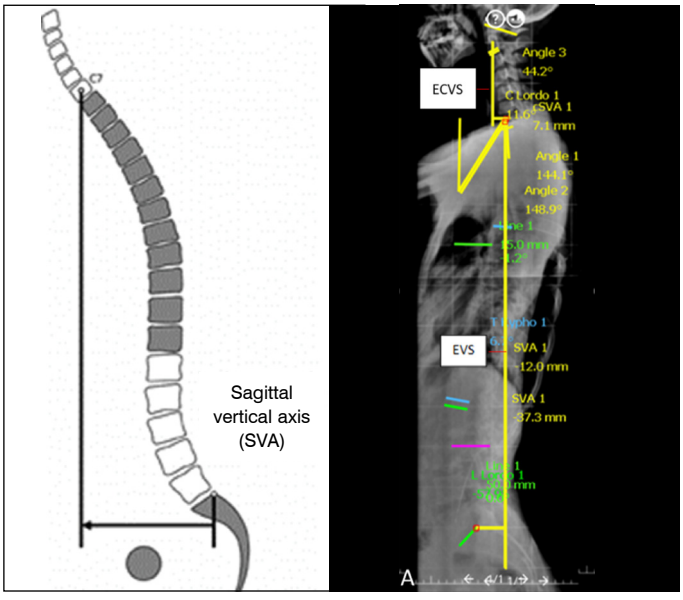

Figure 1. Design and profile radiography of the vertebral column illustrating sagittal vertebral alignment (SVA) measurement.

The parameters selected for the study (SVA, T5-T12 thoracic kyphosis, lumbar lordosis, pelvic incidence, and sacral inclination) were measured (Figure 2) by two independent evaluators, and the Inter-observer agreement coefficient ranged from good to excellent (0.61 to 0.98) in all parameters selected for the study. The main curves in the coronal plane (main thoracic and thoracolumbar/lumbar) were evaluated on AP radiographs. The main curves (thoracic, thoracolumbar/lumbar) were correlated with SVA.

The statistical study was conducted using descriptive statistics, the Kolmogorov-Smirnov test was used to assess the normality of the sample, and the Spearman test was used to assess the correlation between the parameters studied. The significance level established in the study was 0.05% ($p < 0.05$).

RESULTS

Ninety-two patients (84.4%) were female, and 17 (15.6%) were male, with a mean age of 21.8 and 4.9 years old. Forty-eight patients (44.4%) had Lenke type curves 1, 7 (6.4%) Lenke 2, 23 (21.1%) Lenke 3, 5 (4.58%) Lenke 4, 14 (12.8%) Lenke 5, and 12 (11%) Lenke 6. (Figure 3)

The posterior border of S1 is the anatomical reference for evaluating the vertical sagittal axis SVA, which is conventionally considered positive when preceding S1 and negative when later.[7] Normal SVA values depend on the patient's age, and the presence of cervical spine deformity, and the + 50 mm limit value has been considered normal.[7-9] The SVA in 109 patients with AIS ranged from -208 to 66.30 mm (mean -19.64 36.21) and did not show normal distribution (*Kolmogorov-Smirnov* test). The median value was -20.20 mm. The confidence interval for values of 95% of the mean ranged from -26.51 to 12.77. Figures 4, 5, and 6 represent the variation and distribution of SVA values. The SVA was above 50 mm in two patients (1.83%).

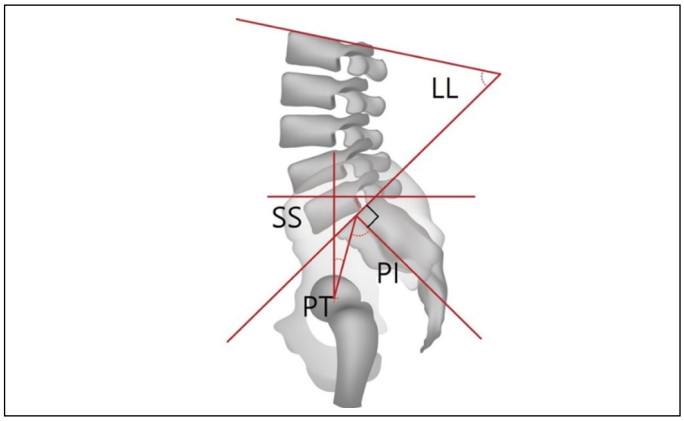

Figure 2. Sagittal parameters were selected in the study. Lumbar lordosis (LL), pelvic incidence (PI), pelvic torsion (PT), and sacral inclination (SS).

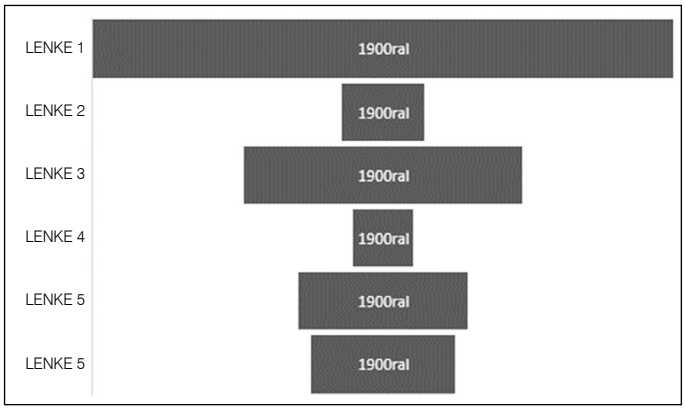

Figure 3. Distribution of curve types among 109 patients with scoliosis, according to the Lenke classification.

Among the two patients with VAS above 50 mm, one had a 1AN curve according to Lenke's classification (main chest curve -48 degrees) (Figure 7), and the other had a 3CN curve (main chest curve 82.4 degrees). (Figure 8)

The term correlation is used in statistics when two variables vary, and the correlation coefficient (r) quantifies the direction and magnitude of the correlation. The correlation coefficient (r) ranges from +1 to -1. The value +1 means perfect positive correlation, and -1 means perfect negative or inverse correlation.

The correlation between SVA and sagittal spinal parameters is illustrated in Table 1. There was no statistical correlation between the SVA and the sagittal variables selected for the study. The correlation between the main curve of Lenke types 1, 2, 3, and 4 and the TL/LL curve of types 5 and 6 with the SVA is illustrated in Table 2.

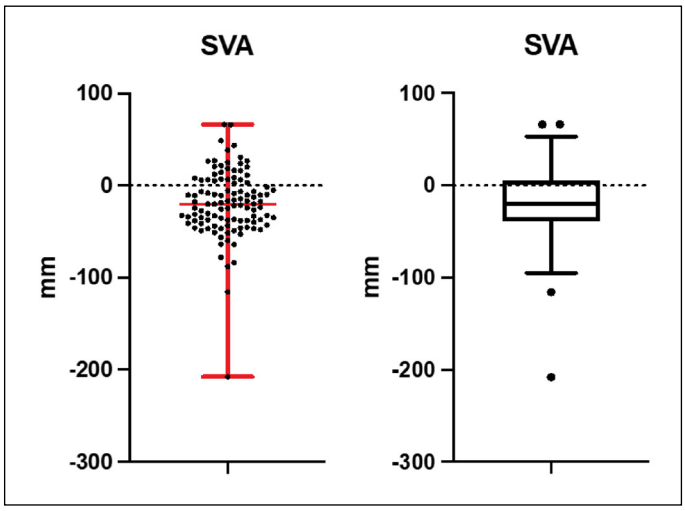

Figure 4. Distribution of vertical sagittal axis (SVA) values, the median and maximum and minimum values (left), and the quartile values (right) of the 109 patients studied.

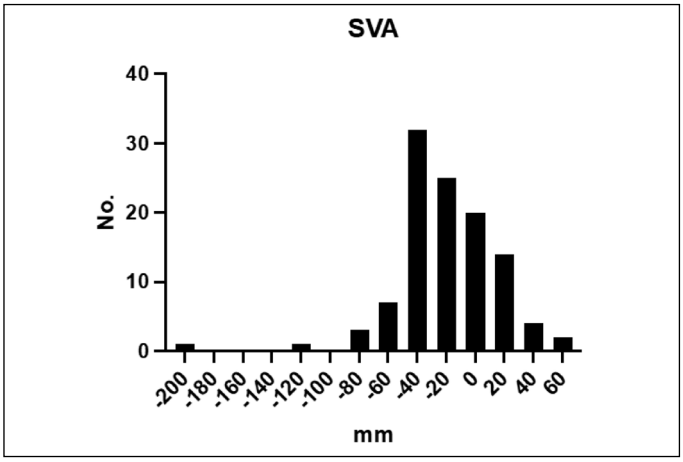

Figure 5. Distribution of vertical sagittal axis (SVA) values in 109 patients with scoliosis.

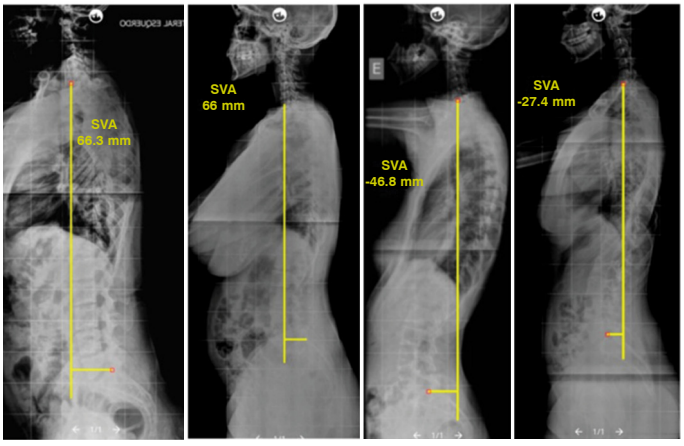

Figure 6. Profile radiographs illustrate the vertical sagittal axis (SVA) variations in patients with adolescent idiopathic scoliosis.

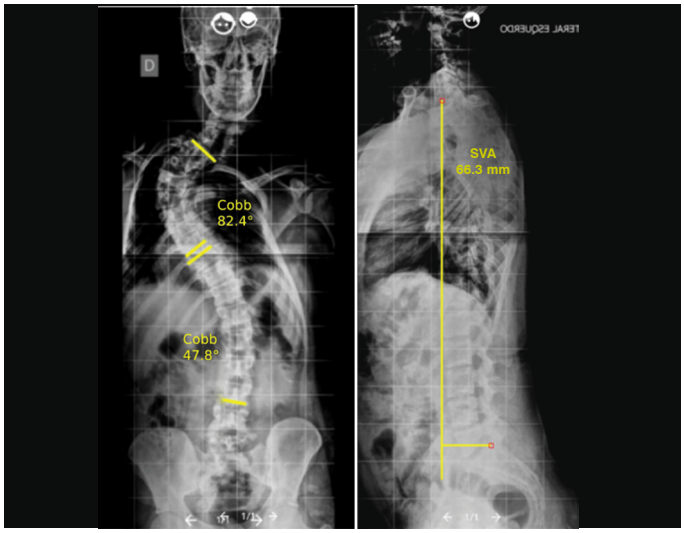

Figure 7. AP radiography and the profile of a patient with adolescent idiopathic scoliosis and misalignment of the vertical sagittal axis (SVA).

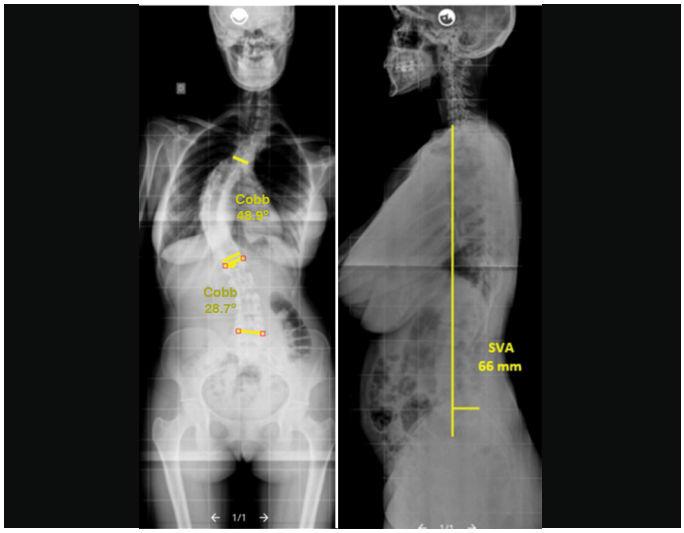

Figure 8. AP radiography and the profile of a patient with adolescent idiopathic scoliosis and misalignment of the vertical sagittal axis (SVA).

Table 1. Data from the correlation analysis between the vertical sagittal axis (SVA) and thoracic kyphosis (TK), lumbar lordosis (LL), pelvic incidence (PI), pelvic torsion (PT), and sacral inclination (SS).

	TK	LL	PI	PT	SS
SVA	0.02533	0.1125	0.1103	0.03062	0.1713
p-value	0.7937	0.2442	0.2605	0.7554	0.0777

Table 2. Values of the correlation coefficient (r) between the vertical sagittal axis (SVA) and the main curves (MT- principal thoracic and TL/LL - thoracolumbar/lumbar).

	MT	TL/LL
SVA	0.05084	0.1542
p-value	0.6585	0.4519

DISCUSSION

The prevalence of sagittal spinal misalignment in the AIS in the present study was 1.83% (2/109 patients). There was no correlation between VAS and thoracic kyphosis, lumbar lordosis, pelvic incidence, pelvic torsion, and sacral inclination. There was no correlation between the magnitude of the main curve (thoracic or thoracolumbar/lumbar) and the VAS.

The lack of correlation between the SVA and the magnitude of the main curves agrees with other reports in which a correlation between the SVA and the coronal parameters was not observed.[10-13] The changes in sagittal alignment are independent of the type and magnitude of the curve in the coronal plane.[14] The results observed suggest that changes in the coronal plane have a small influence on the VAS, corroborating previous reports, which suggest that pelvic parameters, such as pelvic incidence, influence sagittal alignment. More importantly What are the changes in the coronal plane.[15]

We did not observe a statistical correlation between SVA and sagittal parameters. However, there are reports of higher PI and PT values in patients with positive VAS compared to patients with negative AVA.14 Compensatory mechanisms accompany the increase in PT in patients with AIS, and the reduction of thoracic kyphosis has been observed in these patients.[13,15] The increase in PT reflects the compensatory retroversion of the pelvis to maintain the center of gravity over the femoral heads and sagittal balance. The degree of IP is directly related to the capacity of the compensation mechanism. Individuals with higher IP have a greater capacity to perform pelvic retroversion but require a higher degree of lordosis.[13,15]

A low percentage of sagittal misalignment was observed according to our established normal limit value (50 mm). The range of observed values is in line with other reports.[13,15-17] However, trunk imbalance in patients with AIS has been reported to be related to sensory disorders, and higher percentages have been reported, considering misalignment with negative values,[18] while considering as misalignment only the previous displacements of the trunk, represented by positive values. Coronal trunk imbalance has been described as a higher percentage than sagittal imbalance and has a greater influence on clinical evaluation.[18] A slight subsequent deviation of the VAS has already been observed in patients with AIS, especially in Lenke type-1[19] curves, and a deviation greater than 2 cm has been reported in 9/29 patients.[9]

The sagittal alignment of the spine is important in assessing and treating spinal deformities. It has been highlighted in the context of spinal surgery because of its relationship with clinical outcomes.[10-12] Global sagittal spine alignment has classically used the spatial positioning of C7 about the pelvis, using linear, angular, or proportion methods.[7,20] In our study, we adopted the plumb line distance from C7 to the back edge of S1 as a method for evaluating SVA. Although this method is critical in its accuracy,[7] We consider the normal SVA limit to be the values described by Schwab, who considers +50 mm as the limit of the normal value. Still, we must consider that this limit was established based on the correlation between quality of life questionnaires and changes in the sagittal plane in adult deformities.[8]

The objective of our study was to evaluate sagittal alignment in a group of patients with deformities. Although we used this value as a reference, the main objective was to observe the distribution of SVA in the group of patients with AIS and indication for surgical treatment. This group of patients had significant changes in coronal plane deformity, and the possible manifestation of this deformity on the VAS was the reason for the study. However, we did not consider the posterior deviation above 40 mm as an imbalance or only the rear edge of the sacrum, disagreeing with parameters used in other studies.[14,9]

The study has limitations due to its retrospective nature and the acquisition of panoramic radiographs performed during the operational routine. The positioning of the patients, changes in posture, and measurement errors influence the values of sagittal parameters.[20,21]

The profile radiographs of the patients in our study were performed with the upper limbs in a flexed position and supported on support. It has been reported that the flexed position of the upper limbs entails a subsequent displacement of the SVA.[7] This fact must be considered when analyzing the results of our study; the positioning on profile radiographs may have influenced the values of the SVA due to its subsequent displacement. The SVA can move up to 3 cm behind the position with the upper limbs without flexion.[6] The rear displacement of the SVA with the upper limbs in flexion ranged from 2 to 11 cm. It is associated with the subsequent rotation of the pelvis, reinforcing the hypothesis that the assessment of the VAS with the upper limbs in flexion does not represent the precise functional position of the spine.[7] The normal sagittal alignment of the normal vertebral column does not necessarily require SVA equal to zero, and deviations from alignment may be related to anatomical anomalies.[21,22]

The real correlation between changes in coronal and sagittal plane curves in patients with AIS remains poorly understood, although the coupling and interaction of the planes are recognized.[1] Adolescents and young adults are particularly resistant to sagittal plane misalignment and use different mechanisms for postural accommodation.[23] The mechanism for compensating sagittal alignment in patients with AIS has been speculated in literature reports.[2,3,5] Thoracic hypokyphosis, which is present in patients with AIS, is an important mechanism of compensation in patients with sagittal spinal misalignment.[13] However, thoracic hypokyphosis occurs in all patients with AIS, regardless of the degree of the curve PI, and these patients have good spinal muscles. Perhaps the hypokyphosis observed in patients with AIS is a morphological characteristic and not a compensatory mechanism.[24,25]

CONCLUSION

The SVA showed great variability in patients with AIS who presented curves with indications for surgical treatment. The low percentage of patients with misalignment demonstrated the compensatory capacity of young patients with vertebral deformities to compensate for sagittal misalignment of the vertebral column.

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

CONTRIBUTIONS OF THE AUTHORS: Each author contributed individually and significantly to the development of this article. LAMM: surgery, data collection, preparation of the research project, statistical analysis, and writing of the manuscript. MPD: statistical analysis, results interpretation, and manuscript writing. LFMMO: surgery and data collection. VTGS: surgery and data collection. GBLA: surgery and data collection. AEPAJ: surgery and data collection. JAP: preparation of the research project and review of the manuscript.

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