TOMOGRAPHIC ANALYSIS OF SUBAXIAL CERVICAL VERTEBRAE IN CHILDREN BETWEEN 0 AND 12 YEARS

ANÁLISE TOMOGRÁFICA DAS VÉRTEBRAS CERVICAIS SUBAXIAIS EM CRIANÇAS DE 0 A 12 ANOS

ANÁLISIS TOMOGRÁFICA DE VERTEBRAS CERVICALES SUBAXIALES EN NIÑOS DE 0 A 12 AÑOS

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ABSTRACT

Objective: Tomographic and anatomic analysis of cervical vertebrae in children from 0 to 12 years of age to verify the possibility of utilization of lateral mass screws. Methods: Twenty-five cervical spine tomographies of children between 0 and 12 years of age, admitted to the emergency room of Hospital das Clínicas of São Paulo were retrospectively analyzed. The following distances were measured: width and length of the lateral masses in the axial section; width and height in the coronal section; height, length and diagonal diameter in the sagittal section. The variables studied were correlated with age and sex and submitted to statistical analysis. Results: The analysis of tomographic measurements of 20 patients showed a correlation between age and dimensions of the lateral mass, which were higher after 6 years of age. In relation to sex, greater measures were observed in males in all axes. With regard to the passage of the screws, we only had 22 masses (11%) that prevented their use. However, when stratified by age, we noticed that no patients had restrictions on the use of the lateral mass screw after the age of 6. Conclusion: This study analyzed the measurements of 200 lateral masses, making it possible to infer that there is an increase of dimensions with age and in males. Through the data, it was possible to affirm that in this sample, considering the implants available in the market, the lateral mass screws could be used in 89% of the lateral masses.

Keywords: Spine; Tomography, X-Ray computed; Axis, cervical vertebra; Child.

RESUMO

Objetivo: Análise tomográfica e anatômica das vértebras cervicais em crianças de zero a doze anos de idade para verificar a possibilidade de passagem de parafuso de massa lateral. Métodos: Foram analisadas retrospectivamente 25 tomografias de coluna cervical de crianças entre 0 e 12 anos de idade, admitidas no pronto socorro do Hospital das Clínicas de São Paulo. Foram aferidas as seguintes medidas: largura e comprimento das massas laterais no corte axial; largura e altura no corte coronal; altura, comprimento e diâmetro diagonal no corte sagital. As variáveis estudadas foram correlacionadas com a idade e o sexo dos indivíduos e submetidas a análise estatística. Resultados: Por meio da análise de medidas tomográficas de 20 pacientes, foi verificada a correlação entre idade e dimensões das massas laterais, sendo estas maiores a partir dos 6 anos. Já em relação ao sexo, foram verificadas medidas maiores no sexo masculino em todos os eixos. Com relação à passagem dos parafusos, tivemos apenas 22 massas (11%) com impossibilidade de uso. Porém, quando estratificados pela idade, notamos não haver pacientes com impedimento para uso do parafuso de massa lateral após os 6 anos. Conclusão: O estudo analisou as medidas de 200 massas laterais, possibilitando inferir que existe aumento das suas dimensões com a idade e no sexo masculino. Através dos dados, foi possível afirmar que nesta amostra, considerando-se os implantes disponíveis no mercado, o parafuso de massa lateral poderia ser utilizado em 89% das massas laterais.

Descritores: Coluna vertebral; Tomografia computadorizada por Raios X; Vértebra cervical áxis; Criança.

RESUMEN

Objetivo: Análisis tomográfico y anatómico de las vértebras cervicales en niños de hasta doce años de edad, para comprobar la posibilidad de pasaje de tornillos de masa lateral. Métodos: Se analizaron retrospectivamente 25 tomografías computarizadas de la columna cervical de niños entre 0 y 12 años de edad, ingresados en el servicio de urgencias del Hospital das Clínicas de São Paulo. Se tomaron las siguientes medidas: anchura y longitud de las masas laterales en corte axial; anchura y altura del corte coronal; altura, longitud y diámetro diagonal en el corte sagital. Las variables se correlacionaron con la edad y el sexo de los individuos y se sometieron a análisis estadístico. Resultados: Mediante el análisis de las mediciones tomográficas de 20 pacientes, se observó la correlación entre la edad y las dimensiones de las masas laterales, que son más grandes a partir de los 6 años de edad. En relación con el sexo, se observaron medidas más altas en los hombres en todos los ejes. En cuanto al paso de los tornillos, encontramos sólo 22 masas (11%) que impidieron su uso. Sin embargo, cuando se estratificó por edad, observamos que no había ningún impedimento para el uso de tornillo de masa lateral después de 6 años de edad. Conclusión: El estudio examinó las medidas de 200 masas laterales, por lo que es posible inferir que hay un aumento de tamaño con la edad y en el sexo masculino. De estos datos, fue posible afirmar que en esta muestra, teniendo en cuenta los implantes disponibles en el mercado, el tornillo de masa lateral podría ser utilizado en el 89% de las masas laterales.

Descriptores: Columna vertebral; Tomografía computarizada por Rayos X; Vértebra cervical axis; Niño.

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INTRODUCTION

The subaxial region of the cervical spine corresponds to the interval between the third cervical vertebra (C3) and the seventh cervical vertebra (C7). The incidence of severe fractures in this region with neurological damage is 16.5/100.000 per year.[1] Due to this predisposition of this region to injury, surgical and anatomical studies are of general interest.

There are various surgical techniques that enable fixation in the subaxial skeleton via the posterior route. The techniques currently most widely used are those that use screws that can be fixed to the lateral masses or to the pedicles.[2]

Lateral mass screws, which are safe and easy to implant, are practically routinely indicated in the treatment of subaxial cervical lesions in adult patients. However, small lateral masses, which result in the placement of small-diameter screws, have less resistance to screw pull-out than transpedicular screws, which can only be inserted into C1, C2 and C7.[2-3]

The main problem with the use of transpedicular screws in the cervical region is the technical difficulty of their insertion, due to the dimension of the pedicles, the impossibility of using this technique in the segment between C3 and C6, and the risks of severe complications, such as lesion of the vertebral arteries, spinal cord and nerve roots.[4-6] The use of intraoperative radioscopy can help in the placement of these screws.

Thus, searching for a safe option for the treatment of subaxial lesions in pediatric patients, we find in the literature the studies of Lee et al.,[6] and Al-Shamy et al.[7] that show the safety of inserting lateral mass screws with diameters of 3.5mm, which is possible in patients from 4 years of age. However, to date, there is no work analyzing the same parameters in the Brazilian population and respecting our population parameters.

The technique of lateral mass screw insertion is considered simple. It involves bilaterally dissecting the lamina and the lateral mass at the desired level, and performing perforation and inclination, depending on the technique to be used: Roy-Camille or Margel. After perforation, the orifice is palpated and the inner corticals should be felt. A 3.5mm screw is then inserted.[7]

For preoperative evaluation and planning of a patient requiring subaxial cervical fixation, a computed tomography of the cervical spine is requested, after first evaluating the possibility of inserting the screws.

The objective of this work is to analyze 200 lateral masses of pediatric patients, linking their measurements with sex, age, and the possibility of using the lateral mass screw.

MATERIAL AND METHODS

After approval by the ethics committee of the Institute of Orthopedics and Traumatology, under number 15831, we began the study with a retrospective analysis of 25 computed tomographies performed at the general and orthopedic emergency rooms/departments at the Hospital das Clínicas complex of the Faculty of Medicina of the Universidade de São Paulo (HC FMUSP), between the years 2014 and 2015.

Patients aged between 0 and 12 years were selected, by convenience and consecutive sampling, and data were collected relating to the patient's age and sex. Cases were excluded that presented cervical fractures or abnormalities of the spine, such as deformities, neoplasias and rheumatologic diseases. Of the 25 tomographs analyzed, 5 were excluded from the evaluation because they contained some of the exclusion criteria.

The linear and angular dimensions were calculated based on a study proposed by Abdullah et al.[8] In the axial section, the width and length of the lateral masses between C3 – C7 were measured (Figure 1). In the coronal section, the height and width of the lateral masses of the same interval were measured (Figure 2). In the sagittal section, according to the protocols proposed in the literature, the height, length, diagonal diameter and angle of inclination were measured, at the same levels as those mentioned above (Figures 3a, 3b and 3c). The measurement was performed based on the model of the figures, taking into consideration the corticals. All the measurements were collected in millimeters (mm) and the morphometric analysis was performed with the program iSite PACS Philips Healthcare Informatics®.

The statistical analysis was performed with the program SPSS 24 for OSX®. Data were obtained on the mean, standard deviation, minimum and maximum values. The values obtained for each of the variables were correlated with the age groups, sex of the individuals, and the possibility of using a lateral mass screw of minimum size (3.5mm x 10mm). The comparisons were performed by the Student *t* test, with a level of significance of $p<0.05$.

RESULTS

Twenty-five tomographs were analyzed. Five were excluded; 3 because they had some congenital anatomical alteration in the region, and 2 because they had fractures in the region studied. We analyzed the 20 remaining tomographs; 13 from males and 7 from females. The mean age of the patients was 79.65 months (variance of 23 to 142 months). No statistical difference was found between the groups, when comparing age and sex, p= 0.802. In total, 200 lateral masses were examined. The following anatomical parameters were found for each axis.

Axial axis

In the axial section, the possible measurements to be checked are width and length. For the measurement of width of the lateral masses (Table 1), no statistical relationship with sex was found only

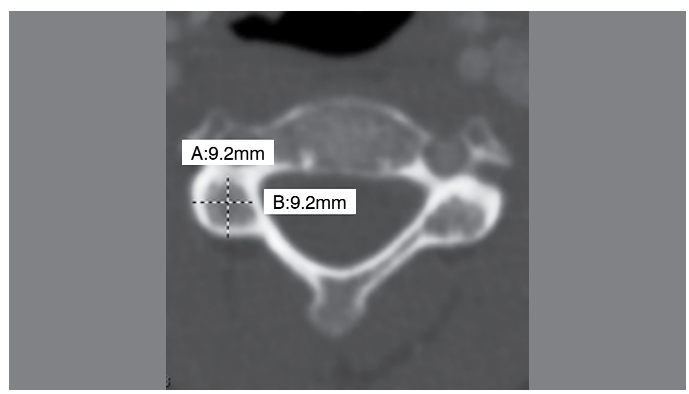

Figure 1. Length (A) and width of the lateral mass (B) in the axial section.

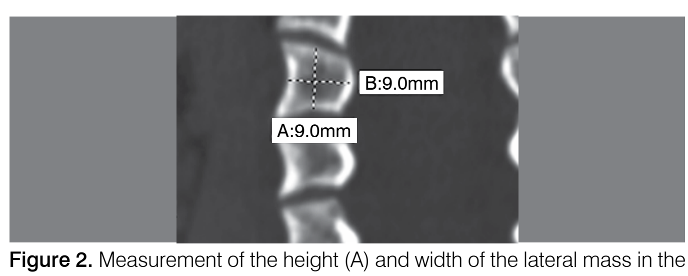

Figure 2. Measurement of the height (A) and width of the lateral mass in the coronal section (B).

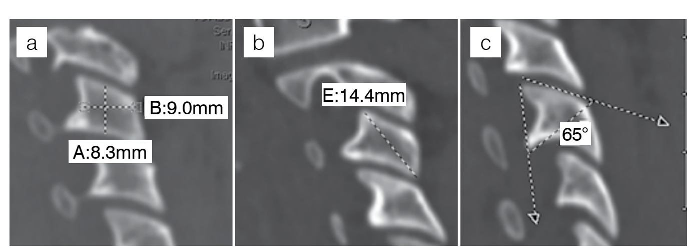

Figure 3. Sagittal section. Measurement of height (A) and length (B) (3a). Measurement of the diagonal diameter (E) (3b). Measurement of the angle of inclination (3c).

for C3. For length, we did not find a relevant statistical association with sex only for C4 (Table 1). However, in males, we found an increase in both axes compared with females.

In relation to age, we found a statistical association, with a greater longer axial length in patients aged over 6 years. This correlation was found for all the lateral masses. In the width measurement, however, a relationship was found only for C6, noting that this lateral mass is larger in those aged over 6 years (Table 1).

The possible measurements in the coronal axis are height and width. The height measurement of the lateral masses of the vertebrae between C3 - C7 present values (Table 2) in which no statistical difference was identified in relation to sex. In relation to coronal width, we find a statistical result only for the mass of C7, with larger measurements for males (Table 2).

In the coronal axis, we found that coronal height is related to age, and was greater for the patients aged over 6 years in all the lateral masses studied. Evaluating coronal width, we were not able to correlate its relationship of increase with age only in the masses of C3 and C4 (Table 2).

In the sagittal section, the relevant measurements to be measured are: height, length, diagonal diameter and angle of inclination. In relation to height (Table 3), no statistically significant association was found between the measurements of the lateral masses and sex. In the measurement of length, we found results with statistically significant association, demonstrating the increase in measurements in males (Table 3).

Linking the same data with age, we found, in all the lateral masses, the relationship that sagittal height is greater for patients aged over 6 years; however, we were not able to find any statistically relevant relation when comparing length with age (Table 3).

The measurements in the sagittal axis of the diagonal diameter (Table 4) do not present relevant statistical relation when compared with the patients' sex. For the measurement of the angle of inclination, we found a significant result only for the mass of C5 (Table 4), which was greater for males.

In relation to the comparison with age, we found results with statistical association that demonstrate that the diagonal diameter is greater for patients over 6 years, but when comparing the relationship between the measurements of the masses and the sagittal angle, we found an inverse relationship, in which the angles are greater in patients over 6 years (Table 4).

After finding the values of the lateral masses, we applied the initial concept that a commercially available lateral mass screw has an average diameter of 3.5mm and a length of 10mm. We therefore consider an error of 1mm for the diameter axis to be safe, enabling us to infer that any measurement less than 4.5mm in any axis, or less than 10mm of the length of the screw in the diagonal diameter, would be an impeditive factor for the use of the screw in that mass.

The result was that of a total of 200 lateral masses, only 22, i.e. 11%, could not be used to insert screw. When we stratified these data by age, we found that from 6 years, no lateral mass presented an impediment to the insertion of the screw (Figure 4).

Relating the findings to the vertebral levels, we found that there is no predilection by anatomical level, and we found no statistical relationship (Figure 5).

In relation to axis, we found that the axis with greater limitation to the passage of the screw is the sagittal axis, and that within this axis, the measurement of sagittal height is the one that most influences this impossibility (Figures 6 and 7).

DISCUSSION

The subaxial cervical region is characterized by a zone of great susceptibility to trauma. The technical difficulties for passage and effective fixation of screws in pediatric patients makes the management and treatment of these patients difficult. Fixation at these levels may be followed by the use of lateral mass or transpedicular screws.

The greatest challenge to the use of transpedicular screws in the subaxial cervical region is the technical difficulty of inserting the screws.[9-12] The small dimension of the pedicles and the angulation

Table 1. Measurements of the axial axis.

Axial width	General	Male	Female	p	Age >6 years	Age >6 years	p
C-3	7.77 ± 1.05	7.96 ± 0.92	7.43 ± 1.23	0.136	8.04 ± 0.94	7.45 ± 1.12	0.077
C-4	7.53 ± 0.79	7.74 ± 0.65	7.13 ± 0.88	0.018	7.60 ± 0.55	7.44 ± 1.02	0.556
C-5	7.24 ± 1.16	7.52 ± 1.07	6.70 ± 1.17	0.032	7.51 ± 0.98	7.10 ± 1.08	0.21
C-6	6.93 ± 1.06	7.19 ± 1.00	6.45 ± 1.02	0.034	7.25 ± 0.96	6.55 ± 1.07	0.038
C-7	6.38 ± 1.07	6.79 ± 1.03	5.69 ± 0.76	0.002	6.60 ± 1.07	6.12 ± 1.03	0.16
Axial length							
C-3	9.14 ± 1.16	9.46 ± 1.00	8.55 ± 1.23	0.015	9.57 ± 1.06	8.62 ± 1.08	0.009
C-4	9.04 ± 0.94	9.24 ± 0.61	8.67 ± 1.31	0.067	9.34 ± 0.75	8.67 ± 1.03	0.023
C-5	9.02 ± 1.17	9.48 ± 0.94	8.18 ± 1.10	0.0003	9.49 ± 0.75	8.45 ± 1.34	0.007
C-6	8.85 ± 1.17	9.23 ± 0.98	8.13 ± 1.20	0.003	9.40 ± 0.93	8.17 ± 1.09	0.0004
C-7	8.38 ± 1.29	8.71 ± 1.13	7.76 ± 1.38	0.025	8.96 ± 1.17	7.66 ± 1.07	0.001

Correlation of the measurement of the lateral masses found in the axial axis and its relationship with age and sex. Values: Mean ± Standard Deviation (mm), *t* test valid if $p<0.05$.

Table 2. Measurements in the coronal axis.

Coronal height	General	Male	Female	p	Age >6 years	Age >6 years	p
C-3	8.28 ± 1.63	8.24 ± 1.34	8.35 ± 2.12	0.838	9.31 ± 1.33	7.02 ± 0.92	0.00001
C-4	7.25 ± 0.79	7.17 ± 1.17	7.39 ± 1.61	0.628	7.98 ± 1.00	6.36 ± 1.11	0.00002
C-5	7.53 ± 1.53	7.30 ± 1.39	7.95 ± 1.73	0.204	8.35 ± 1.00	6.52 ± 1.48	0.00001
C-6	7.52 ± 1.60	7.38 ± 1.19	7.78 ± 2.20	0.534	8.33 ± 1.38	6.52 ± 1.26	0.00001
C-7	6.93 ± 1.48	6.77 ± 1.23	7.22 ± 1.88	0.371	7.75 ± 1.06	5.93 ± 1.31	0.00003
Coronal width							
C-3	9.90 ± 1.13	10.22 ± 1.01	9.33 ± 1.15	0.016	10.0 ± 1.11	9.75 ± 1.17	0.457
C-4	9.83 ± 0.96	10.15 ± 0.79	9.23 ± 0.97	0.002	10.0 ± 0.83	9.59 ± 1.07	0.154
C-5	9.76 ± 1.08	10.20 ± 0.91	8.94 ± 0.88	0.0001	10.1 ± 0.79	9.34 ± 1.25	0.023
C-6	9.54 ± 1.21	9.84 ± 1.08	8.99 ± 1.28	0.033	9.85 ± 0.94	9.17 ± 1.40	0.091
C-7	10.21 ± 1.46	10.43 ± 1.36	9.80 ± 1.60	0.197	10.9 ± 1.39	9.36 ± 1.06	0.0004

Correlation of the measurement of the lateral masses found in the coronal axis and its relationship with age and sex. Values: Mean ± Standard Deviation (mm). *t* test valid if $p<0.05$.

Table 3. Measurements in the sagittal axis.

Sagittal height	General	Male	Female	p	Age >6 years	Age >6 years	p
C-3	6.90 ± 1.42	7.01 ± 1.25	6.69 ± 1.72	0.506	7.94 ± 0.90	5.62 ± 0.71	0.00001
C-4	6.34 ± 1.30	6.39 ± 1.16	6.24 ± 1.58	0.759	7.28 ± 0.77	5.18 ± 0.77	0.00003
C-5	6.59 ± 1.33	6.55 ± 1.35	6.65 ± 1.34	0.819	7.53 ± 0.89	5.43 ± 0.74	0.00001
C-6	6.40 ± 1.54	6.36 ± 1.37	6.47 ± 1.88	0.835	7.42 ± 1.32	5.16 ± 0.61	0.00004
C-7	5.61 ± 1.28	5.77 ± 1.13	5.32 ± 1.53	0.292	6.33 ± 1.11	4.7 ± 0.87	0.00002
Sagital length							
C-3	8.08 ± 1.09	8.44 ± 1.03	7.40 ± 0.89	0.003	8.46 ± 1.00	7.61 ± 1.04	0.012
C-4	8.35 ± 0.90	8.66 ± 0.76	7.76 ± 0.87	0.002	8.40 ± 0.91	8.28 ± 0.92	0.694
C-5	8.36 ± 1.04	8.62 ± 1.05	7.87 ± 0.86	0.029	8.59 ± 0.95	8.08 ± 1.10	0.124
C-6	8.15 ± 1.01	8.41 ± 1.03	7.67 ± 0.82	0.028	8.18 ± 0.93	8.11 ± 1.13	0.833
C-7	7.54 ± 1.19	7.93 ± 1.07	6.81 ± 1.09	0.003	7.50 ± 0.97	7.60 ± 1.45	0.792

Correlation of the measurement of the lateral masses found in the sagittal axis and its relationship with age and sex. Values: Mean ± Standard Deviation (mm). t test valid if $p<0.05$.

Table 4. Measurements of the sagittal axis - Complementary.

Diagonal diameter	General	Male	Female	p	Age >6 years	Age >6 years	p
C-3	12.71 ± 2.07	12.69 ± 1.79	12.74 ± 2.60	0.953	14.1 ± 0.99	10.9 ± 1.64	0.00001
C-4	13.68 ± 2.19	13.60 ± 1.76	13.82 ± 2.91	0.795	15.3 ± 1.27	11.7 ± 1.25	0.00001
C-5	13.65 ± 2.12	13.36 ± 1.59	14.17 ± 2.87	0.34	15.1 ± 1.33	11.8 ± 1.41	0.00002
C-6	14.58 ± 2.51	14.43 ± 2.02	14.8 ± 3.31	0.677	16.3 ± 1.69	12.4 ± 1.51	0.00001
C-7	14.61 ± 2.47	14.59 ± 2.00	14.65 ± 3.26	0.953	16.3 ± 1.48	12.5 ± 1.76	0.00001
Sagittal angle							
C-3	70.8 ± 10.7	70.8 ± 11.4	70.6 ± 9.53	0.947	67.5 ± 10.7	74.8 ± 9.40	0.029
C-4	68.2 ± 9.23	69.7 ± 9.84	65.5 ± 7.56	0.17	64.0 ± 6.96	73.3 ± 9.27	0.01
C-5	67.7 ± 9.25	70.0 ± 9.35	63.28 ± 7.51	0.025	64.3 ± 6.86	71.7 ± 10.3	0.01
C-6	60.9 ± 8.75	61.8 ± 8.48	59.3 ± 9.32	0.398	56.7 ± 7.62	66.1 ± 7.29	0.0003
C-7	55.0 ± 9.07	56.1 ± 8.64	52.9 ± 9.79	0.289	50.4 ± 8.35	60.6 ± 6.5	0.0001

Correlation of the measurement of the lateral masses found in the sagittal axis and its relationship with age and sex. Values: Mean ± Standard Deviation (mm), t test valid if $p<0.05$.

of attack for insertion of these screws makes the surgical procedure difficult. The use of intraoperative radioscopy can help in the placement of these screws.[13] Meanwhile, the positioning of the radioscopy to obtain adequate images may be difficult in some cases.

The anatomical variations in the dimensions, and morphology of the lateral masses, make the use of the screws impossible in certain situations. Even under direct visualization, cortical ruptures were identified in 8-13% of patients.[2,14]

A good knowledge of the local anatomy is a primordial factor for surgical success, enabling neurological damage to be avoided. In terms of the spectrum of our work, we found in the international literature a work by Al-Shamy et al.,[7] which evaluates, in similar form, the proportions of lateral mass and the possibility of using screws in these regions.

The unique feature of our work in relation to that of Al-Shamy et al.[7] is that besides evaluating the dimensions of the lateral masses for a sample of the Brazilian population (0-12 years), we also evaluated the statistical part, correlating it with the mean age (6 years), instead of an arbitrary value of 8 years, which was not explained in that work. Another factor that differentiates our work relates to the restriction of diameter of the lateral mass screw. In the work of Al-Shamy et al.[7] a diameter of 4.0mm was used as a safety measure, which was considered small by the authors, as an error of 0.5mm in a diameter of 4.0mm is equivalent to just 12.5% of the axis. In this case, we consider a value of 1mm above 3.5 mm to be an impeditive factor.

In our study, we found statistically significant differences in the relationship between sex and age in relation to the measurements found for the lateral masses. Although it was not possible to achieve statistical values for some axes, we conclude that the N of 20 patients or 200 lateral masses may be insufficient to reach any conclusion about those respective levels or axes.

Of the total of 200 lateral masses measured, we found only 22 in which the lateral mass screw could not be used, 11% of which were in patients below 6 years. Although the result did not present statistically significant difference, and it is only a finding in the measurements, we can suggest that a study with a greater N may provide more information about the safest age for the use of these screws.

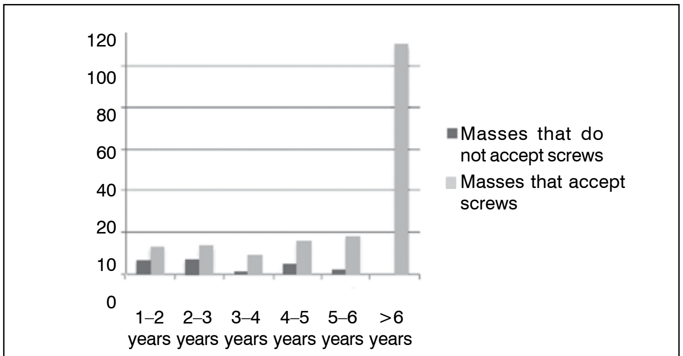

Figure 4. Relationship between lateral masses that accept the screw and age.

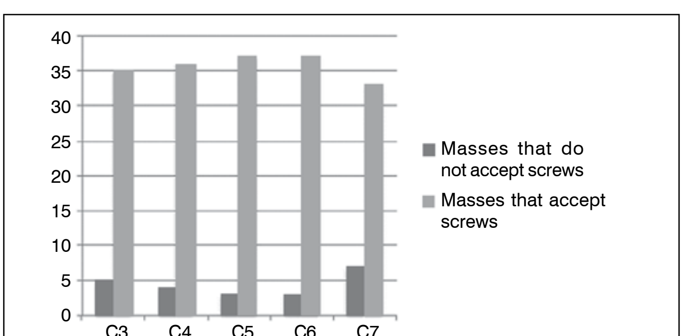

Figure 5. Relationship between lateral mass and vertebral level.

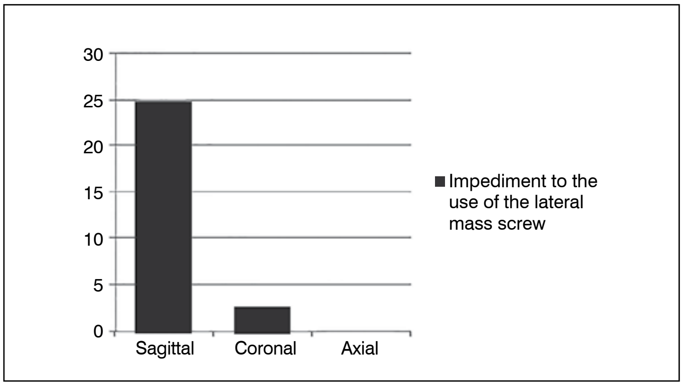

Figure 6. Number of impediments to the use of the lateral mass screw and its relationship with axis.

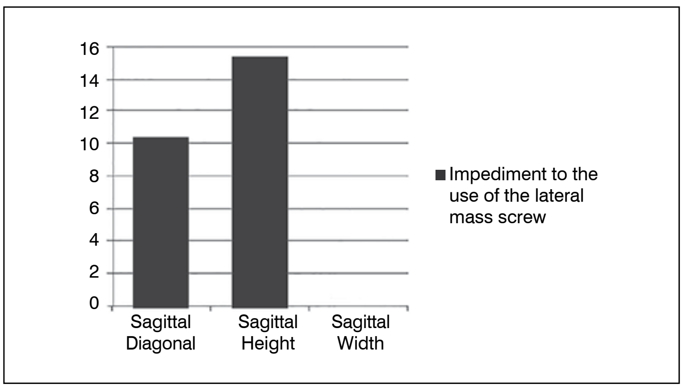

Figure 7. Number of impediments to the use of the lateral mass screw and its relationship with the measurements of the sagittal axis.

Among the axes, the greatest limiting factor for the use of same was the sagittal axis, with 24 impediments (the same mass can be an impediment in various axes) compared with 2 of the coronal axes and none of the axial axes. In relation to measurement, sagittal height was the measurement that most limited the use of the lateral mass screw, and should therefore be carefully observed in the preoperative planning.

With the increased number of CT performed at the emergency room/department of the Hospital das Clínicas, which include this age range, we will probably be able to add more patients to our database, in order to achieve statistical value to define the age from which the use of the lateral mass crew is safe for children of the Brazilian population.

CONCLUSION

Our study managed to evaluate the measurements of the lateral masses for the Brazilian population, enabling us to infer that the lateral masses increase with age, and to demonstrate that the lateral masses are larger for males in some parameters. Based on the data obtained, we can affirm that in this sample, considering the implants available in the market, the lateral mass screw can be introduced in 89% of the lateral masses of our study, and no impediment is found to the use of the device, provided it is well planned prior to the surgery.

We also mention the need to look very closely at the preoperative measurements, taking special care with the sagittal axis.

All the authors declare that there is no potential conflict of interest in relation to this article.

CONTRIBUTIONS OF THE AUTHORS: Each author made an individual and significant contribution to the development of this manuscript. LCCM and OBL were the main contributors to the writing of the manuscript and setting up the intellectual concept of the manuscript. RMM and AFC were responsible for the patient selection and bibliographic research, prior to the study. RPO and TEPBF reviewed the manuscript.

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