TOMOGRAPHIC ANALYSIS OF ANATOMICAL PARAMETERS OF THE AXIS IN CHILDREN

Alessandro Gonzalez Torelli, Rafael Bellucci Kohlmann, Olavo Letaif Biraghi, Alexandre Sadao Lutaka, Alexandre Fogaça Cristante, Raphael Martus Marcon

ABSTRACT

Objective: To carry out an anatomical study of the axis with the use of computed tomography (CT) in children aged from two to ten years, measuring the lamina angle, lamina and pedicle length and thickness, and lateral mass length. Methods: Sixty-four CTs were studied from patients aged 24 to 120 months old, of both sexes and without any cervical anomaly. The measurements obtained were correlated with the data on age and sex of the patients. Statistical analysis was performed using the Students "t" tests. Results: We found that within the age range 24-48 months, 5.5% of the lamina and 8.3% of the pedicles had thicknesses of less than 3.5mm, which is the minimum thickness needed for insertion of the screw. Between 49 and 120 months, there were no lamina thicknesses of less than 3.5mm, and 1.2% of the pedicle thicknesses were less than 3.5mm values. Neither of the age groups had any lamina and pedicle lengths of less than 12mm, or lateral mass lengths greater than 12mm. Conclusion: The analysis of the data obtained demonstrates that most of the time, is possible to use a 3.5mm pedicle screw in the laminas and pedicles of the axis in children. ***Level of Evidence: II, Development of diagnostic criteria in consecutive patients.***

Keywords: Axis. Bone screws. Tomography. Spinal fusion.

Citation: *Torelli AG, Kohlmann RB, Biraghi OL, Iutaka AS, Cristante AF, Marcon RM. Tomographic analysis of anatomical parameters of the axis in children. Acta Ortop Bras. 2012;20(2):75-8. Available from URL: http://www.scielo.br/aob.*

INTRODUCTION

The upper cervical spine is composed of the occiput, atlas and axis. Half of the cervical flexion movement (between the occiput and C1) and half of the cervical rotation movement (C1-C2) occur in this region. The C1 vertebra is ring-shaped, presenting two lateral masses, with articular facets and absent vertebral body.

The C2 vertebra has a vertebral body, with dentiform bone process that articulates with the anterior arch of C1, having two lateral masses and two laminas.

The C1 and C2 vertebrae are stabilized by bone structures (odontoid process) and ligament structures (transverse ligament and alar ligament).

One of the main aspects in relation to the anatomy of C1-C2 is the location of the vertebral artery,[1] which runs through the transverse foramen of C1, looping on both sides in the posteromedial direction up to its point of entry in the occipital foramen. This structure, therefore, is at risk during the passage of screws in both vertebrae.[1,2]

It is known that the upper cervical spine is frequently affected by pathologies that require some kind of surgical treatment, such as rheumatoid arthritis, Down syndrome, fractures, dislocations and ligament lesions. Countless techniques were described for fixation of the high cervical spine aiming at stable intervertebral fusion. Wiring techniques such as those of Brooks or Gallie are relatively simple procedures, yet have the disadvantage of requiring rigid immobilization after surgery, besides presenting high rates of pseudarthrosis (up to 30%).[2,3] With the development of the synthesis materials, techniques arose that allow more stable fixation. The two methods most often used today are: the Jeannert and Magerls[4] transarticular screw fixation technique and the Harms and Melcher C1 lateral mass and C2 pedicle technique.[5] Both techniques, from the biomechanical viewpoint, are superior to the wiring technique and also involve the insertion of screws in the pedicles or through the pars interarticularis of C2, posing a significant risk for the vertebral artery, as hemorrhages, neurological sequelae and even death could occur.[1,4-7]

Wright and Lauryssen[6] described a new fixation technique at C2 in ten cases. The technique consists of the passage of screws in the C2 laminas and achieved, according to another study by the same author, stability similar to that of the Magerl

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

Spine Group of the Institute of Orthopedics and Traumatology of Hospital das Clínicas of the School of Medicine of Universidade de São Paulo – São Paulo, SP, Brazil.

Study conducted at LIM 41 – Laboratory of Medical Investigation of the Musculoskeletal System of the Department of Orthopedics and Traumatology of the School of Medicine of Universidade de São Paulo
Mailing address: Rua Oscar Rodrigues Cajado Filho, 204. Vila São Francisco. São Paulo-SP. Brazil. Email: alessandrotorelli@gmail.com

Article received on 09/03/10 and approved on 10/14/10.

and Magerl[4] and Harms and Melcher[5] techniques, without the associated vascular and neurological complications.

Due to the lower risk of complications associated with this technique and the higher success rate of arthrodesis, it becomes an attractive treatment option.

Ferri de Barros et al.[2] conducted a tomographic study comparing the adequacy of fixation screws in C2 pedicles and laminas in children from two to eleven years of age, and obtained data that enable them to infer that the C2 lamina represents a viable point of fixation for C1-C2 and craniocervical arthrodesis in children,[6] which would allow the application of the Wright technique in children.

The objectives of this study were to evaluate the dimensions of the following anatomical structures in the Brazilian pediatric population: lamina, pedicle and lateral mass of C2; and to validate for our population the data obtained with this study.

METHODS

Sixty-four cervical tomographic scans acquired during routine outpatient and emergency care provision in the complex of Hospital das Clínicas of Universidade de São Paulo were analyzed retrospectively.

Patients between two and 10 years of age were selected with the gathering of data referring to their age and sex. The patients were divided into two age groups: from 24 to 48 months and from 49 to 120 months, respectively named group 1 (18 cases) and group 2 (43 cases). Cases that presented anatomical abnormalities in the cervical spine or fracture of the level studied (three cases) were excluded.

Using the ImageJ® imaging program, the dimensions and angulation of the laminas, pedicles and lateral masses were evaluated in an axial section of C2 corresponding to the height midpoint of the lamina (parasagittal section). The thickness of the C2 lamina was measured in millimeters (mm). The measurement was performed at the point of least thickness between the internal cortical layers. Each measurement will be performed in a specific manner for each side of the lamina. (Figure 1) The length (mm) of the laminas was measured in the same axial section. The measurement was performed from the external cortex opposite to the lamina to the limit of the visible length in that section. (Figure 2)

The spinolaminar angle was drawn for both sides, with one of the lines inside the C2 lamina parallel to the cortices of this lamina, and another line passing through the center of the spinous process and odontoid process dividing the vertebra into two hemivertebrae. (Figure 2)

The pedicle thickness was measured in the same axial section, at its narrowest point. (Figure 3) The length in the same section was measured from the point of entry in the lateral cortex to the anterior cortex in the vertebral body. (Figure 3) The length of the lateral mass was measured from the transition of the lamina with the mass to the opposite cortex. (Figure 3)

A statistical analysis with the *SPSS 13.0 for Windows* program was carried out using the *t*-test. Mean, standard deviation, minimum and maximum value data were obtained. The data relating to age, sex and laterality (right and left) were combined with the abovementioned anatomical measurements.

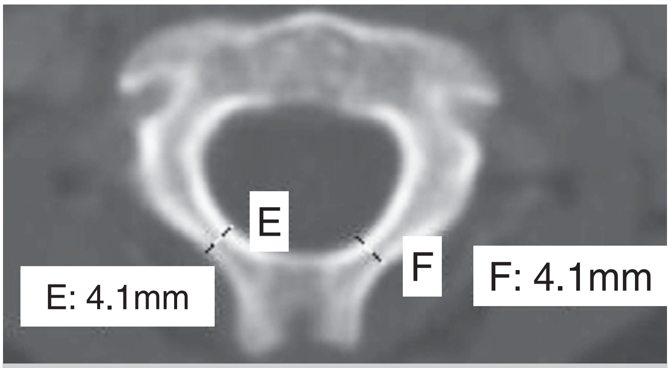

Figure 1. *Measurement of the C2 lamina thickness (E,F).*

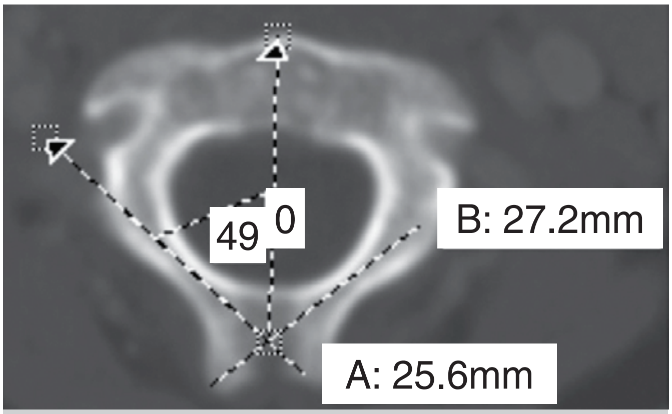

Figure 2. *Measurement of the laminar angle and length (A,B).*

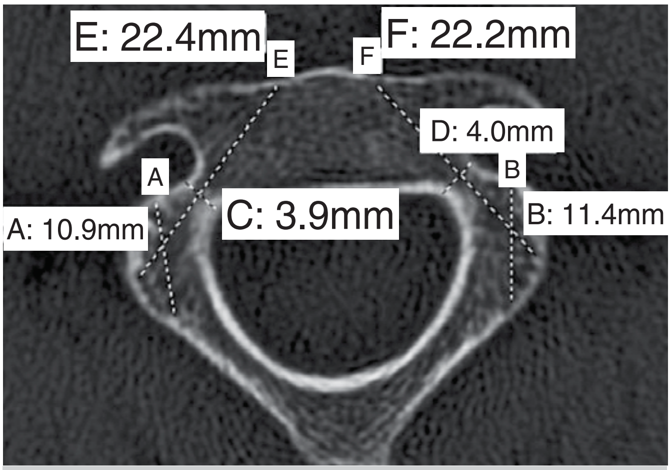

Figure 3. *Measurement of the lateral mass length (A,B), pedicle thickness (C,D) and pedicle length (E,F).*

RESULTS

Of the 64 tomographic scans analyzed, 45 were of the male and 16 of the female sex. Three were excluded from the study as they contained fracture at the level analyzed. The average age of the total group of patients was 66.83 ± 28.93 months; the average age of group 1 was 32.16 ± 9.06 months while that of group 2 was 81.34 ± 20.79 months.

Since no significant difference ($p>0.05$) was observed in the measurements in relation to laterality, the results presented correspond to the measurements obtained without considering the sides.

Tables 1, 2 and 3 present respectively the mean values with the standard deviation and the minimum and maximum values of the anatomical measurements of the lamina, pedicle and lateral mass according to age groups and gender.

In group 1 it was observed that 5.5% of the laminas and 8.3% of the pedicles have a thickness of less than 3.5mm. In group 2 there are no laminas with thicknesses of less than 3.5 mm and only 1.2% of the pedicles have a thickness of less than 3.5mm. The frequency of the lamina and pedicle thicknesses is represented in Figures 4 and 5.

There is no lamina and pedicle length of less than 12mm in either age group.

The spinolaminar angle, measured close to the laminar screw positioning angle, had only 5% of the values below 41°, and 90% are below 51.8° degrees.

We did not record lateral mass lengths of more than 12mm in either age group.

DISCUSSION

In analyzing the data obtained, it was possible to observe that there were no statistically significant differences ($p>0.05$) as regards laterality in either one of the groups, for all the measurements performed. The difference observed between the sexes was not statistically significant.

In group 1 it was observed that only 5.5% of the laminas had a thickness of less than 3.5mm. In group 2 there are no laminas with a thickness below this value. There is no lamina length of less than 12mm in either group. The lowest and highest lamina thickness value obtained was 3.3 and 5.4mm, respectively. It can be concluded that the passage of screws through the lamina is practicable in both groups studied, as in general the smallest screws commercially available for this purpose have a thread diameter of 3.5mm and a length of 12mm.

The spinolaminar angle, in both groups, had only 5% of the values below 41° and 90% was below 51.8° degrees. The smallest angle found was 40° while the largest was 53°. The mean of the spinolaminar angle was 45° in group 1 and 47.1° in group 2, and this information is of practical use in the surgical technique. The data obtained in the two groups considering sex as a variable were not statistically significant ($p>0.05$).

In group 1, it was observed that 8.3% of the pedicles have a thickness of less than 3.5mm, while this value was only 1.2% in group 2. There is no pedicle length of less than 12mm in either group. The lowest and highest pedicle thickness value obtained was 3.1 and 5.6mm, respectively. Although the data obtained show that it is anatomically possible to insert a screw in the pedicle of the pediatric population studied, we should consider the high risk of injury to the vertebral artery[5] with this technique, with a narrow margin of error.

We have various techniques available for fixation of the high cervical spine targeting stable intervertebral fusion. Wiring

Table 1. *Mean anatomical values and variation for the Lamina.*

Lamina							
Age Bracket (Months) Mean MSD		Thickness (mm)		Length (mm)		Angle (degrees)	
		Interval	Mean MSD	Interval	Mean MSD	Interval	
24 - 48	Male	3.96 ± 0.28	3.4 - 4.6	20.23 ± 1.75	17.7 - 23.3	45.19° ± 3.41°	40º - 53º
	Female	3.92 ± 0.34	3.3 - 4.4	19.34 ± 0.81	17.8 - 19.8	43.70° ± 2.26°	41º - 47º
	Total	3.95 ± 0.29	3.3 - 4.6	19.96 ± 1.59	17.7 - 23.3	45.02° ± 3.03°	40º - 53º
49 - 120	Male	4.66 ± 0.35	3.9 - 5.4	24.17 ± 1.29	21.3 - 26.6	47.42° ± 2.78°	42º - 53º
	Female	4.28 ± 0.39	3.6 - 4.9	23.16 ± 2.52	17.4 - 27.2	46.70° ± 2.98°	40º - 53º
	Total	4.56 ± 0.39	3.6 - 5.4	23.92 ± 1.67	17.4 - 27.2	47.13° ± 2.96°	40º - 53º

Table 2. *Mean anatomical values and interval for the Pedicle.*

Pedicle					
Age Bracket (Months) Mean MSD		Thickness (mm)		Length (mm)	
		Interval	Mean MSD	Interval	
24 – 48	Male	4.08 ± 0.42	3.4 - 4.7	18.99 ± 2.02	16.6 - 22.1
	Female	3.92 ± 0.42	3.1 - 4.3	18.53 ± 0.89	17.0 - 20.3
	Total	3.98 ± 0.37	3.1 - 4.7	18.96 ± 1.42	16.6 - 22.1
49 - 120	Male	4.61 ± 0.38	3.9 - 5.6	21.79 ± 1.46	19.1 - 25.8
	Female	4.45 ± 0.55	3.3 - 5.3	20.59 ± 1.65	17.4 - 23.9
	Total	4.59 ± 0.42	3.3 - 5.6	21.59 ± 1.60	17.4 - 25.8

Table 3. *Mean anatomical values and interval for the Lateral Mass.*

Lateral Mass			
Age Bracket (Months) Mean MSD		Length (mm)	
		Interval	
24 - 48	Male	8.38 ± 0.88	7.3 - 11.1
	Female	7.86 ± 0.45	7.3 - 8.8
	Total	8.27 ± 0.79	7.3 - 11.1
49 - 120	Male	9.85 ± 0.59	7.3 - 11.4
	Female	9.16 ± 0.84	8.1 - 10.8
	Total	9.66 ± 0.76	7.3 - 11.4

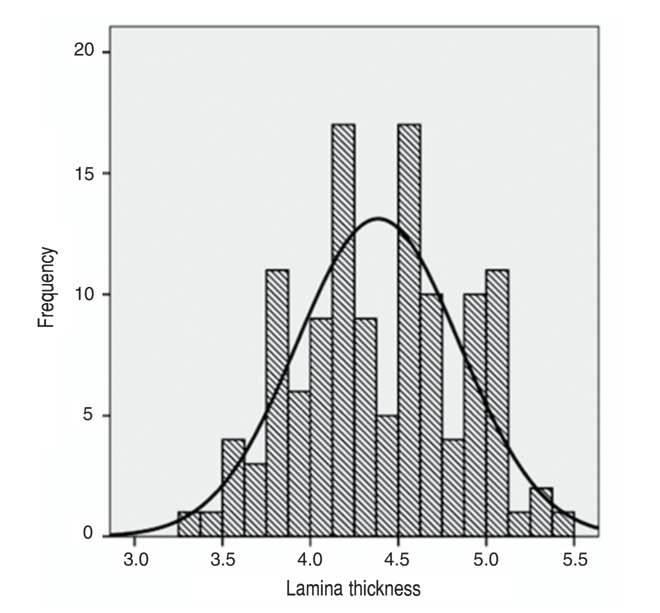

Figure 4. *Frequency versus lamina thickness.*

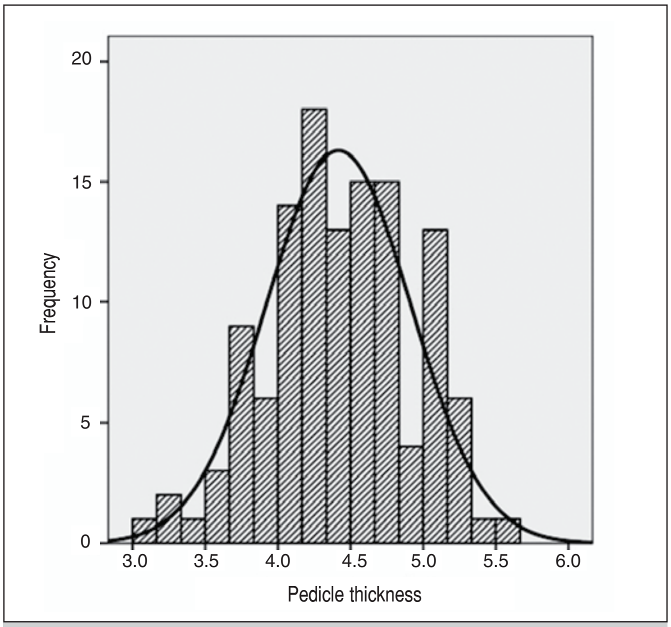

Figure 5. *Frequency versus pedicle thickness.*

techniques such as those of Brooks or Gallie are relatively simple procedures, yet have the disadvantage of requiring rigid immobilization after surgery, besides presenting high rates of pseudarthrosis.[2,3] The Jeannert and Magerls[4] transarticular screw fixation technique and the Harms and Melcher.[5] C1 lateral mass and C2 pedicle technique are more commonly used today. From the biomechanical viewpoint, techniques using screws are superior to the wiring technique but have the disadvantage of the risk of injury to the vertebral artery, spinal cord and roots.[1,4-7]

In comparison to the data obtained by Ferri et al.[2] in 2010 where 24% of the C2 pedicles and 65% of C2 laminas were considered suitable for the insertion of 3.5mm screws, we had a higher percentage of cases in which such passage would be anatomically possible.

The lateral mass length in both groups is around 9mm; hence the fixation technique with lateral mass screw in C2 is not a safe treatment option in the pediatric population studied.

CONCLUSION

The tomographic analysis of the axis in the pediatric population from 2 to 10 years of age showed that the anatomical dimensions studied allow the insertion of screws in the laminas and pedicles in most cases, taking into account the materials available in the market with a diameter of 3.5mm.

In surgical practice in relation to the spinolaminar angle a basal value of around 45° can be adopted as a reference in the insertion of screws in the C2 lamina.

The small length of the lateral mass of C2 observed in the study does not allow the insertion of the smallest screw available in the market for this purpose.

REFERENCES

1. Lau SW, Sun LK , Lai R, Luk MS, Ng YS . Study of the Anatomical Variations of Vertebral Artery in C2 Vertebra With Magnetic Resonance Imaging and Its Application in the C1–C2 Transarticular Screw Fixation. Spine (Phila Pa 1976). 2010;35(11):1136-43.
2. Ferri de Barros F, Litle DG, Bridge C, Cummine J, Cree AK. Atlantoaxial and craniocervical arthrodesis in children: a tomographic study comparing C2 suitability of pedicle and laminae for screw fixation . Spine (Phila Pa 1976). 2010;35(3):291-3.
3. Rocha ID, Jorge DMF, Pasqualin T, Iutaka AS, Rodrigues MB, Oliveira RP, et al. Tomographic analysis for the placemant of laminar C2 screws .Coluna/Columna. 2008;7(2):230-4.
4. Jeanneret B, Magerl F. Primary posterior fusion C1/2 in odontoid fractures: indications, technique, and results of transarticular screw fixation. J Spinal Disord. 1992;5(4):464-75.
5. Harms J. Melcher RP. Posterior C1-C2 fusion with polyaxial screw and rod fixation. Spine (Phila Pa 1976). 2001;26(22):2467-71.
6. Wright NM, Lauryssen C. Vertebral artery injury in C1-2 transarticular screw fixation: results of a survey of the AANS/CNS section on disorders of the spine and peripheral nerves. American Association of Neurological Surgeons/Congress of Neurological Surgeons. J Neurosurg.1998;88(4):634-40.
7. Mandel IM, Kambach BJ, Petersilge CA, Johnstone B, Yoo JU. Morphologic considerations of C2 isthmus dimensions for the placement of transarticular screws. Spine (Phila Pa 1976). 2000;25(12):1542-7.