ORIGINAL ARTICLE

TOMOGRAPHIC STUDY OF THE ATLAS CONCERNING SCREW FIXATION ON LATERAL MASS

MAX FRANCO DE CARVALHO[1,2], ROBERTA TEIXEIRA ROCHA[1], JOÃO TIAGO SILVA MONTEIRO[1], CARLOS UMBERTO PEREIRA[1], RICARDO FERREIRA LEITE[1], HELTON LUIZ APARECIDO DEFINO[2]

ABSTRACT

Introduction: Harms´s technique for atlanto-axial arthrodesis fusion makes possible the use of intraoperative reduction maneuvers of the atlanto-axial dislocation and facilitates the fixation of this joint, especially in hiperkyphotic patients and in situations where the fixation with transarticular screw on C1-C2 segment is impossible. Objective: to describe the morphometric parameters of atlases related to the Harms´s technique for atlanto-axial arthrodesis, the optimal path and the safety aisle for screw insertion into atlas' lateral mass measured with multiplanar reconstruction imaging with helical computed tomography scan at the planes. Materials and Methods: 30 atlases of local origin have been submitted to computed tomography imaging and measured with digital cursor. Results: The posteroanterior length of the implant measured 16.5 mm to the right and 16.3 mm to the left. When using it as entry point at the central portion of the lateral mass just below the posterior arc, the path must have a congruence of 15º in the coronal plan and an upper angle of 20º at the sagittal plane. Conclusion: The safety aisle for screw fixation into the lateral mass would have a lower bending of 22º and an upper bending of 33º at sagittal plane and 36º medially and 26° laterally, at the axial plane.

Keywords: *Atlanto-axial joint. Arthrodesis. Tomography.*

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INTRODUCTION

High cervical spine anatomy is responsible for the segment with the highest degree of mobility in the whole vertebral spine. Due to these unique characteristics, both the first and the second cervical vertebrae present different morphological characteristics from the other cervical vertebrae.[1-4]

Pathologies of the craniocervical joint may be caused by trauma, tumors, congenital malformations or rheumatic pathologies. With the development of imaging diagnostic methods and surgical techniques, a significant increase of the number of surgical procedures was seen on this region.[5,6]

The key objective of most surgical procedures on atlanto-axial joint is to achieve intervertebral union. The most employed arthrodesis techniques are: Brooks- or Gallie-type ligation, interlaminar clamp, Magerl's transarticular technique, translaminar screw on atlas, and screw on lateral mass.[5-16] Atlas fixation with screws on the lateral mass was introduced by Goel and Laheri[14], but the technique was disseminated by Harms and Mecher[15] with the development of a system composed by a polyaxial screw and nail.

Biomechanical studies proved that Magerl's transarticular technique and the screw on C1 lateral mass technique associated to screw at the C2 pedicle provide the same stability level as in laboratory studies.[17] However, these systems are more stable than the different ligation techniques. The size of C2 isthmus can prevent transarticular screw fixation in approximately 20% of the patients.[6]

The possibility of using atlanto-axial dislocation reduction maneuvers after the insertion of screws on C1 and C2 of the lateral mass, has enabled an advancement on reducing and fixating atlanto-axial instability.[15]

In recent years, the safety of Harms' technique has been described in several studies.[12,14,15,17-19] Lateral mass provides a structure that is large enough to accommodate a 3.5-mm screw. However, the near distance from vertebral artery, from the second cervical nerve's ganglion, and from the spinal cord can cause serious iatrogenic injuries should the screw is inserted out of the lateral mass. The objective of this study is to describe the safety zone for fixating screws on the lateral mass of dried vertebrae using a multiplanar reconstruction assay with multiplanar helical computed tomography machine.

MATERIALS AND METHODS

Thirty cervical vertebrae (C1 or Atlas) removed from human unidentified cadavers were obtained by donation of the Urban Services Company (EMURB) of the city of Aracaju – Sergipe – Brazil, according to report nr. 047/2005. The vertebrae were removed from local individuals buried as indigents, and no distinction was made concerning gender, age or ethnicity. After dissection, cleaning and fixation, the vertebrae were numbered for subsequent classification and X-ray analysis by means of helical computed tomography (Toshiba Asteion TSX – 021A/1A, 1-mm thick sections). After measurements were performed, 5 vertebrae were randomly selected and tomographically re-scanning and re-measuring these for studying the error.

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1 – Department of Medicine, Federal University of Sergipe, Brazil
2 – Department of Biomechanics, Medicine, and Locomotive Apparatus Rehabilitation, Medical School of Ribeirão Preto -USP, SP, Brazil

Correspondences to: Rua José Seabra Batista, 255; Condomínio: Tyrol; Edifício Innsbruck; Apto:1204, Jardins; Aracaju-Sergipe- Brasil. CEP:49025-750. Email: carvalhomax@hotmail.com

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The screw insertion point was determined by following the Harms' technique [15] at the central portion of the lateral mass just below the posterior arch, as seen on 3-dimensional images. Then, through multiplanar studies, safety zones were found for inserting screw on the lateral mass, following the parameters: anterior height (distance between upper and lower surfaces of the most anterior portion of atlas' lateral mass); lateral height (distance between the insertion point and the lower posterior end of the atlas' lateral mass); posterior height (distance between the upper and lower surfaces of the most posterior portion of atlas' lateral mass); cross-sectional diameter (largest distance from medial surface to the lateral portion of atlas' lateral mass at a cross-sectional foramen level); anteroposterior length (distance between the anterior cortical of atlas' lateral mass at sagittal plane and the insertion point); upper angle (angle between one line of the insertion point up to anterior cortical and atlas' anteroinferior cortical at sagittal plane); lower angle (angle between one line of the insertion point up to anterior cortical and atlas' anteroinferior cortical at sagittal plane); medial angle (angle between one line of the insertion point up to anterior cortical and atlas' medial cortical at coronal plane), and lateral angle (angle between one line of the insertion point up to anterior cortical and atlas' lateral cortical at coronal plane). (Figures 1 and 2).

In order to assess the reproducibility of measurements, a subgroup of five vertebrae was randomly selected, which were submitted to a new tomographic test where measurements were made again by the same investigator, blinded to the results of the first measurement. For assessing intra-investigator variation, the intraclass correlation coefficient (ICC) was calculated.[20,21]

The consistency between both measurements was assessed by means of the ICC and of the corresponding confidence interval (95% confidence).[20,21] For comparing the variables assessed for right and left sides, the linear regression model was adopted. Similarity of sides was assessed by the hypothesis test that the straight line intercept was equal to zero, and that the angle coefficient was equal to one.

RESULTS

Based on the findings of the measurements on the thirty atlas, the median, the mean, maximum, minimum and standard deviation values were calculated. Both linear and angular measurements did not show statistical difference between the values achieved and those seen at error evaluation. The reliability of these measurements is significantly higher than zero. All intraclass correlation coefficient values were close to 1, evidencing its reliability.

On the measurements of anterior height of the lateral mass, a mean value of 17.42 ± 2.04 mm was found to the right and, to the left, the mean value was 17.61 ± 1.88 mm. For lateral heights of the lateral mass, the mean value seen to the right was 3.83 ± 0.63 mm and 3.67 ± 0.61 mm to the left. In both cases, no significant differences were found between right and left sides ($p > 0.05$). Nevertheless, in the measurements for posterior height of the lateral mass, a significant difference was found between right and left sides ($p < 0.05$). The mean value seen for the right was 12.09 ± 2.03 mm and for the left, 12.41 ± 1.99 mm.

For cross-sectional diameter measurements, the mean value found to the right was 18.03 ± 2.58 mm and to the left, 18.42 ± 2.41 mm. For anteroposterior diameter, the mean value found to the right was 16.47 ± 1.85 mm and 16.27 ± 1.74 mm to the left. In both cases, no significant differences were found between right and left sides ($p > 0.05$). (Table 1)

The measurements for lower angle showed a mean value of 23.63 ± 5.25 to the right, and $22.99^{o} \pm 5.62^{o}$ to the left. The measurements for upper angle showed a mean value of $33.73^{o} \pm 6.30^{o}$ to the right, and $34.44^{o} \pm 5.80^{o}$ to the left. The measurements for medial angle showed a mean value of $36.99^{o} \pm 5.25^{o}$ to the right and $36.20^{o} \pm 5.07^{o}$ to the left. The measurements for lateral angle showed a mean value of $26.61^{o} \pm 5.21^{o}$ to the right, and $26.17^{o} \pm 4.98^{o}$ to the left. In all angle measurements, no significant differences were found between right and left sides ($p > 0.05$). (Table 2)

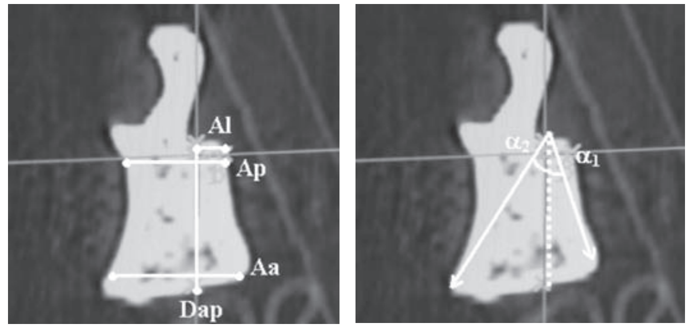

Figure 1 – *Study of the safety zone for inserting screws on atlas' lateral mass through a tomography image at sagittal plane: (Aa) Anterior height; (Al) Lateral height; (Ap) Posterior height; (Dap) anteroposterior diameter; (α1) lower angle; (α2) upper angle.*

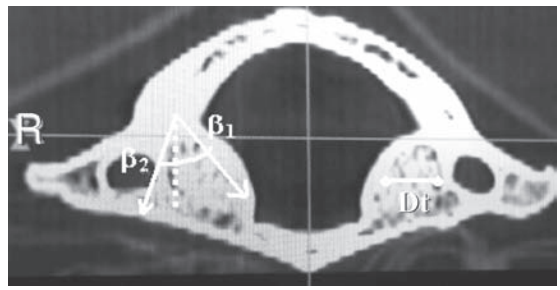

Figure 2 – *Study of the safety zone for inserting screws on atlas' lateral mass through a tomography image at coronal plane: (Dt) cross-sectional diameter; (β1) medial angle; (β2) lateral angle*

DISCUSSION

Since Magerl and Seemann[16] first described the transarticular arthrodesis technique, biomechanical studies have evidenced the biomechanical superiority of this fixation method in all motion planes of the atlanto-axial joint, including the rotation, when compared to the other ligation techniques.[12,14,15,17-19]

Atlas fixation achieved a great advancement, after the dissemination of a system using polyaxial screws on the lateral mass of C1 and on the pedicle of C2 by Harms and Melcher[15], which enabled the use of peroperative reduction maneuvers of the atlanto-axial dislocation and made the fixation of this joint easier, especially on hyperkyphotic patients. The biomechanical study by Melcher et al.[17] did not show significant difference between this new method and the transarticular fixation.

According to Harms and Melcher[15] and Melcher et al.[17] the screw insertion point on the lateral mass must be located at the middle of the posterior C1 arch joint and the middle of the lower portion and posterior surface of the lateral mass. The screw path should be straight or a little medially convergent towards the posteroanterior plane, parallel to C1 posterior arch at sagittal plane towards the anterior arch. On the description of the technique, the need to palpate lateral masses with a Penfield-like retractor protecting the vertebral artery, the vertebral canal, and the second cervical nerve has always been emphasized.

Tan et al.[19] reported atlas fixation through posterior arch. The inser-

Table 1 – *Linear Measurements for Surgical Technique Evaluation*

	Anterior Height		Lateral Height		Posterior Height		Cross-sectional Diameter		Anteroposterior Diameter	
	R	L	R	L	R	L	R	L	R	L
Minimum	13.60	14.20	2.60	2.70	8.60	7.60	13.50	13.70	13.00	13.00
Maximum	22.70	21.40	5.10	5.30	16.30	16.10	26.30	24.80	19.70	20.70
Median	17.15	17.95	3.75	3.60	11.75	12.75	17.55	18.10	16.65	16.40
Mean	17.42	17.61	3.83	3.67	12.09	12.41	18.03	18.42	16.47	16.27
SD	2.04	1.88	0.63	0.61	2.03	1.99	2.58	2.41	1.85	1.74

Table 2 – *Angle Measurements for Surgical Technique Evaluation*

	Lower angle		Upper angle		Medial angle		Lateral angle	
	R	L	R	L	R	L	R	L
Minimum	13.10	13.20	21.60	24.10	29.10	26.70	14.30	19.80
Maximum	33.50	32.50	43.70	46.00	48.80	44.00	37.70	38.00
Median	23.80	24.10	33.35	33.45	36.45	37.20	25.70	26.15
Mean	23.63	22.99	33.73	34.44	36.99	36.20	26.61	26.17
SD	5.25	5.62	6.30	5.80	5.25	5.07	5.21	4.98

tion point would be at 19.01 mm laterally to the mean line of the posterior arch, and at 2.03 mm superiorly to the lower edge of the posterior arch. The thickness of the vertebral groove would be 9.51 $\pm$ 2.09 mm to the right, and 9.68 $\pm$ 2.40 mm to the left. Of the 50 studied vertebrae, only 4 (8%), the thickness of the posterior arch has shown to be thinner than 4 mm. In these cases, the fixation must be made through lateral or transarticular mass. Ebraheim et al.[22] measured the dimensions of the vertebral artery groove and found that the thickness of the vertebral groove was 4.1$\pm$ 1.2 mm. After an anatomical and X-ray study of dried atlas removed from Brazilian cadavers, Carvalho et al.[23] found a mean inter-investigator thickness of 3.87 $\pm$ 0.83 mm to the right and 3.92 $\pm$ 1.10 mm to the left. These findings precluded fixation through the posterior arch as suggested by Tan et al.[19]

Honget al.[24] conducted an anatomical study of the lateral mass of 30 atlas and found that the screw insertion point would be an intersection point between the lower edge of the posterior arch and the center of the lateral mass. The optimal end point for the screw would be situated at 3-4 mm from the lower joint facet. The screw should be preferably inserted with a convergence of 15^{o} and with a cephalic bend of 23^{o} at sagittal plane.

At the insertion place recommended in our study, the lateral mass showed a mean width of 18.03 mm on the right and 18.42 mm on the left, posterior height of the lateral mass of 12.09 mm on the right and 12.41 mm on the left. All studied vertebrae showed enough space for a safe fixation of a 3.5 mm-thick screw on the lateral mass. However, a height comprehended between the insertion point and the lower edge of the lateral mass was 3.83 mm on the right and 3.67 mm on the left. In these cases, the surgeon must resect 10 mm of the atlas' posterior arch to enable an easy screw insertion.

In an anatomical study, Wang and Samudrala[25] described how to position a screw on the lateral mass, which should have a straight direction. However, a maximum medial and lateral angulation of 33° and 13°, respectively, would be allowed at the coronal plane, and a maximum upper and lower angulation of 19^{o} and 0^{o}, respectively, at sagittal plane.

According to our findings, the screw on lateral mass should be approximately 16 mm long. When using an insertion point at the central portion of the lateral mass just beneath the posterior arch, the path should have a congruence of 15^{o} at coronal plane, and an upper angle of 20^{o} at sagittal plane. The safety zone for a screw on lateral mass would be a lower and upper bending of 22^{o} and 33^{o} respectively at the sagittal plane, and a medial and lateral bending of approximately 36° and 26°, respectively, at the axial plane.

CONCLUSION

The fixation with screw on atlas' lateral mass is certainly a surgical technique that enabled spine surgeons to achieve better outcomes in cases of atlanto-axial joint dislocation. Our study has shown that, in all atlas studied here, this technique is a safe procedure. However, the preparation of the insertion point and the awareness of the safety zone for inserting the screw are critical factors for avoiding an iatrogenic injury.

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