POSTERIOR INSTRUMENTATION FOR LAMINAR SCREW OF C2: A DIMENSIONAL ANATOMIC STUDY OF AXIS

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ABSTRACT

Introduction:The atlantoaxial joint has stabilizing mechanisms (bones, ligaments and capsules) keeping the anatomic relation between C1-C2. When one or more of those mechanisms fail, in a traumatic or non-traumatic way, an instability atlantoaxial occurs leading to neurologic impairment, pain and cervical mobility limitation. Neurologic impairment and moderate to severe instability may need surgical treatment. Since 1910, a great number of C1-C2 stabilization techniques have been developed, and, even recently, new methods have been developed. New techniques using bilateral screws on C1 lateral mass and C2 laminar screws connected by rods were developed. Objective: To measure C2 lamina size in order to evaluate the safety and the dimension of the screw used in Wright´s technique. Metods: We conducted an anatomic study with 29 human adult cadavers whose C2 laminas were dissected and measured, in sagittal, coronal and axial planes. Results: The average measure of the external middle portion of C2 lamina was 5,83mm, and 8,93% were below 3,5mm. Conclusion: We suggest a tomographic study prior to surgery in order to identify patients with smaller laminas, thus presenting a higher risk.

Keywords: *Axis. Bone screws. Spine. Atlanto-axial joint. Instrumentation.*

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INTRODUCTION

Atlanto-axial joint stability is provided by C1-C2 stabilizing mechanisms, which include: alar ligaments, Atlas cross-like ligament (transverse, upper and lower longitudinal), apical ligament, tooth of Axis, joint capsule, anterior and posterior Atlanto-axial membrane, tectorial membrane, joint facets, C1 and C2 bone integrity, among other passive and active mechanisms. If one or more fail, atlanto-axial instability of traumatic, non-traumatic or congenital etiology would result, ultimately leading to neurological changes, pain, and/or restricted cervical motion.

Surgery is usually reserved for patients with neurological deficit and in cases of moderate to severe instability.[1] Indications for posterior C1-C2 stabilization are numerous and include type-II and type-III odontoid process fractures (when associated to Jefferson fracture or atlanto-axial joint fracture and failure of other treatment methods), congenital C2 malformations (e.g., odontoideum and odontoid agenesia), degenerative diseases, inflammatory diseases, tumors, infections associated to atlanto-axial instability, postoperative instability (laminectomies and joint facet removal), C1-C2 ligament laxity with augmented atlanto-dental interval (e.g., rheumatoid arthritis).

The assessment of currently available C1-C2 arthrodesis techniques suggest that fixation with intralaminar screws on C2 may reduce the risk of neurological injuries, while increasing success rates in arthrodeses and reducing the risk of pseudoarthrosis.

The objective of this study was to measure, by dissecting cadaver's posterior C2 elements, the internal and external dimensions of C2 lamina in order to assess the safety and size of screws to be used.

MATERIALS AND METHODS

An anatomical study on 29 adult (> 18 years old) cadavers sourced by the Death Examination Service of University of São Paulo's Medical School, as approved by the committee of ethics of University of São Paulo's Hospital das Clínicas. The pieces were randomly selected between June 2006 and June 2007.

Exclusion criteria included the following:

– cervical surgery;
– history of cervical trauma;
– osteometabolic diseases;
– rheumatic diseases;
– immature skeleton, and;
– congenital cervical abnormalities.

The cadavers were preserved, and no decomposed cadavers were used.

The study starts with the body in pronation with a head support, providing a posterior longitudinal access port (approximately 10 cm) to the high cervical spine. The posterior arch of the second

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cervical vertebra is carefully dissected, as well as the arches of the first and third cervical vertebrae. The spinous process, the laminae and C3 pedicles are resected *in situ*, favoring an appropriate positioning of the instrumentation and the osteotomy of C2 pedicles. The block, including a portion of the pedicles, lateral masses, laminae and the spinous process is resected with delicate chisel and saws.

Any adhered soft part is carefully resected from posterior C2 arch, leaving the anatomical piece composed only by bone. These are measured with an accurate pachymeter and goniometer, with the following parameters being checked:

1. Total laminar length (C), at cross-sectional plane, measured between the center of the spinous process and the beginning of lateral masses (Figure 1a)
2. Laminar thickness (cross-sectional plane) measured at three points: close to spinous process (medial – M), close to lateral mass (lateral – L) and at mid-distance between these two measurements (mid – m). (Figure 1b)
3. Laminar height (sagittal plane) measured at three points: close to spinous process (medial – M), close to lateral mass (lateral – L) and at mid-distance between these two measurements (mid – m). (Figure 2)
4. Interlaminar angle (β) formed by anterior portions of C2 laminae, the vertex of which is the base of spinous process (Figure 3).

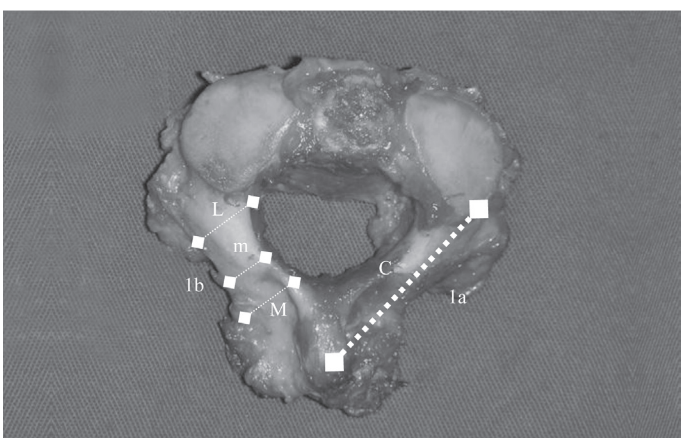

Figure 1 – *Upper view of the Axis (Dried anatomical piece):*
a: External laminar length (C);
b: External laminar thickness, medial (M), mid (m) and lateral (L).

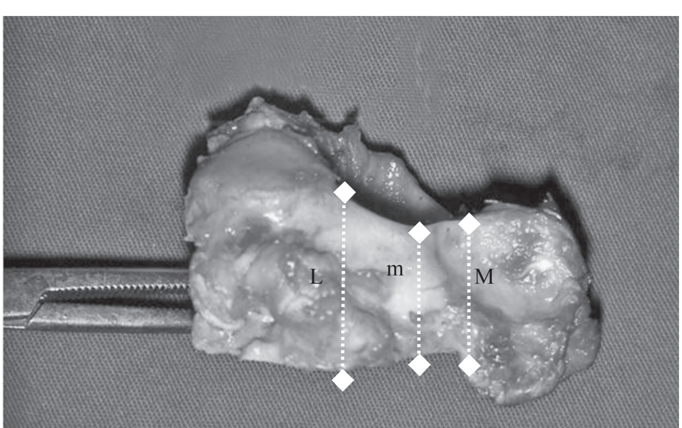

Figure 2 – *Dried anatomical piece, lateral view, showing the three measurement points for external height, medial (M), mid (m) and lateral (L).*

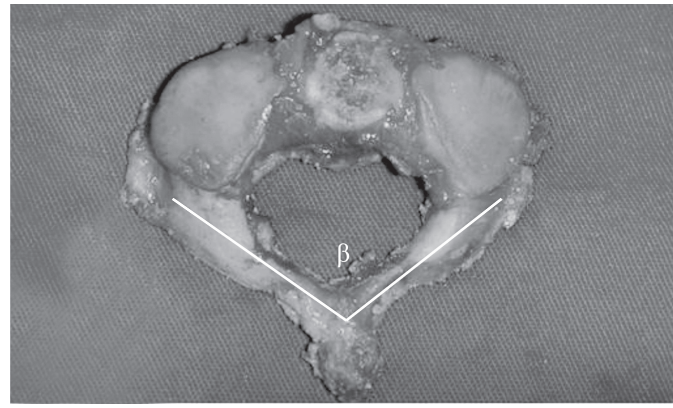

Figure 3 – *Interlaminar angle.*

After measuring these points, the pieces are cross-sectioned (Figure 4) at the center of its height using a delicate saw. Then, the following parameters are measured:

5. Internal laminar thickness (cross-sectional plane), measured from the thickness of laminar spongy bone, inner interval between bone tables forming laminae, measured at three points, close to spinous process, close to lateral mass and at half distance between these two measurements.
6. Internal laminar length (cross-sectional plane) distance between spinous process base and the union between lamina and contralateral paars.

After measuring these points, a statistical analysis is carried out with the interlaminar angle, length and width of C2 lamina (both intramedullar and extracortical) comparing these values to available laminar screws, showing if there is enough intramedullary space for this kind of fixation.

The descriptive statistical analysis was carried out with the mean and standard deviation values for the measurements taken on pieces.

Figure 4 – *Cross-section of C2:*
a: internal laminar length (c);
b: internal thickness medial (M), mid (m) and lateral (L).

RESULTS

Twenty-eight cadavers were assessed, after one case was excluded for presenting C2-C3 vertebrae fusion. In this sample, there were 20 men and nine women, including eleven Caucasians, ten non-Caucasians and eight African-descendents.

The mean age of the cadavers was 58.71 years (range: 31-91). The mean height was 1.71 meters, ranging from 1.60 to 1.90. They weighted, in average, 67.10 kilos (49.9 to 85) and all deaths were resultant from clinical factors, without associated trauma.

The mean angle between C2 laminae was 88.61 degrees (range: 72 - 110) and other measurements are shown on tables 1 to 5.

DISCUSSION

Since 1910, countless surgical C1-C2 stabilization techniques have been practiced for treating C1-C2 instabilities, and, recently, new C1-C2 stabilization techniques are being developed. In 1910, Mixter and Osgood[2] described the ligation technique for C1-C2 spinous processes with silk; in 1939, Gallie[3] described the ligation of C1-C2 laminae; in 1978, Brooks and Jenkins[4] described an alternative C1-C2 laminae ligation method, which was subsequently modified by Dickman and Sonntag.[5] In 1980, interlaminar clamps[6] became popular. Posterior fixation with transarticular C1-C2 screws and screws on C1 lateral mass, on C2 pedicle and lamina were more recently developed.

All these techniques are susceptible to failure, complications and technical challenges. Sublaminar ligation techniques, passing through C1 arch[3], or double passing through C1 and C2[4] present risks of neurological injuries inherent to the act of passing

Table 1 – *Measurements of external laminar length (mm)*

	Patient	R- Ext	L - Ext
	1	36	38
	2	32	35
	3	39	37
	4	36	39
	5	41	42
	6	38	37
	7	40	41,5
	8	33	34
	9	33	35
	10	36	36
	11	34	35
	12	34	36
	13	39	40
	14	36	38
	15	37	38,5
	16	27	25
	17	27	25
	18	26	24
	19	25	24
	20	20	17
	21	29	28
	22	27	24
	23	20	20
	24	21	22
	25	20	21
	26	19	19
	27	17	17
	28	27	27
Mean		30.32	30.53
Standard Deviation		7.30	8.13

Table 2 – *Measurements of external right and left laminae thickness in its medial, mid and lateral portions (mm)*

		External Thickness - Right			External Thickness - Left		
	Patient	Medial	Mid	Lateral	Medial	Mid	Lateral
	1	7	7	9	8	6	6
	2	8	7	8	7.5	7	8
	3	5.5	4.5	6	7	6	7
	4	6.2	4.8	6	8	6.3	8
	5	8	6	9	7	5	10
	6	9	6	7	9	6	8
	7	10	9	10	10	7.5	8
	8	6	4.5	7.5	5	4	5.5
	9	8	5	7	6	6	8
	10	11	7	8	10	7	9
	11	6	5	5.5	6	5	6
	12	6	5.5	6.5	8	6	7.5
	13	9	7.5	9	9	7	9
	14	7.5	7	8	8	6.5	8
	15	8	6	8	7.5	6	8
	16	4	3	6	4	4	6
	17	4	3	5	4	3	5
	18	5	5	7	5	4	6
	19	5.5	5	6.5	5.5	5	6
	20	4	3	7	4.5	4	5
	21	6	5	9	8	7.5	8.5
	22	6	5	9	6	5	8
	23	6	4	8	6	3	7
	24	6	5	8	7	6	8
	25	7	7	10	8	7	10
	26	14	12	12	12	10	12
	27	7	5	6	8	5	6
	28	11	9	11	12	9.5	10
Mean		7.16	5.80	7.81	7.35	5.86	7.62
Standard Deviation		2.31	1.97	1.69	2.09	1.67	1.68

Table 3 – *Measurements of right and left laminae height in its medial, mid and lateral portions (mm)*

		Right Coronal Plane Height			Left Coronal Plane Height		
	Patient	Medial	Mid	Lateral	Medial	Mid	Lateral
	1	12	12	15	14	13	17
	2	15	13	14	16	13	14
	3	13	11	12	13	12	14
	4	14	13	12	13	13	14
	5	16	12	16	13	12	13
	6	12	11	13	11	12	14
	7	14	13	18	13	13	16
	8	14.5	13	15	14.5	12	13.5
	9	14	12	13	14	11	12
	10	11	11	13	12	12	13
	11	11.5	11	12	12	11.5	12
	12	13	12	14	12.5	12	13
	13	15	13	16	15	13	15
	14	13	12	14	13	12	15
	15	14	12.5	14	15	13	15
	16	11	9	11	10	8	11
	17	10	8	12	11	9	11
	18	13	11	13	13	12	13
	19	12	10	13	12.5	10.5	13
	20	12	12	16	12	12	13
	21	12	12	14	12.5	11	13
	22	13	10	16	14	12	17
	23	16	12	16	16	13	17
	24	12	11	15	13	12	14
	25	10	10	7	11	10	8
	26	6	6	12	6	6	11
	27	12	11	10	12	10	10
	28	12.5	11.5	14	15	12.5	12
Mean		12.62	11.25	13.56	12.82	11.51	13.34
Standard Deviation		2.04	1.60	2.21	2.01	1.65	2.10

Table 4 – *Measurements of right and left internal laminar length (mm)*

	Patient	Right	Left
	1	34	30
	2	36	37
	3	33	40
	4	29	39
	5	34	35
	6	30	30
	7	34	32
	8	28	28
	9	30	28
	10	38	38
	11	29	28
	12	29	31
	13	36	38
	14	33	35
	15	35	36
	16	25	24
	17	19	19
	18	23.5	25
	19	24	25
	20	24	23.5
	21	31	28
	22	28.5	28
	23	37	32
	24	25	24
	25	27	29
	26	28	25
	27	24	22
	28	30	30
Mean		29.78	29.98
Standard Deviation		4.78	5.60

Table 5 – *Measurements of internal right and left laminar thickness (mm)*

	Right Lamina			Left Lamina			
	Patient	Medial	Mid	Lateral	Medial	Mid	Lateral
	1	5	4	6	5	4	7
	2	6	5	7	6	5	7
	3	9	2	4	7	2	4
	4	6	4	6	5	6	7
	5	8	3	3	1	2	5
	6	5	4	5	6	3	4
	7	10	6	8	9	6	9
	8	4	3	5	3	2.5	5
	9	5	3	6	5	3	5
	10	11	6	8	11	4	6
	11	5	3	5	3	2.5	3.5
	12	5.5	3	5	5	3	5
	13	10	6	8	9	5.5	8
	14	7	4	5	6	4	7
	15	7	4	6	6	4	6
	16	3	3	4	3	3	5
	17	3	2	4	3	2	3
	18	4	3	5	4	2	4
	19	4	3.5	4.5	4	3	5
	20	4	3	6	3.5	3	5
	21	4	3	7	4	3	6
	22	3	2.5	5	3.5	2.5	5
	23	7	2	5	8	2	7
	24	4	3	6	5	4	6
	25	4	2	4.5	5	2	7
	26	3	4	9	3.5	3.5	8
	27	5	1	7	5	2	7
	28	3	4	6	3	4.5	5
Mean		5.51	3.42	5.71	5.05	3.32	5.76
Standard Deviation		2.31	1.23	1.43	2.20	1.22	1.47

sublaminar wires, in addition to the need of a stiff external orthosis and a high rate of arthrodesis non-union, which can range from 9% to 20%.[7-9] Some authors state that non-union is related to little mechanical stability, especially rotational, provided by techniques using ligation alone (Gallie or Brooks-Jenkins).[10-14]

The technique described by Magerl[15] shows good stability and several clinical studies evidenced its effectiveness in obtaining arthrodesis and good clinical outcomes. It uses a three-point fixation system, with two transarticular C1-C2 screws (right and left) associated to ligation, similarly to the technique by Gallie. No stiff orthosis is required, and arthrodesis rates are high.[15,16] However, anatomical studies showed that vertebral artery can be damaged by that technique, especially when anatomical changes are present on its path close to C2 paars (medial or superior migration of the artery), preventing the use of this technique in up to 20% of the cases.[16-20] This technique becomes unfeasible when a non-reducible C1 sub-dislocation > 50% occurs over C2.[21] The verticalized screw insertion angle may represent an additional technical challenge, preventing its use in patients with severe thoracic kyphosis and potentially leading to the need of an enlarged access port up to C6-C7 in order to get the right screw insertion angle.[22]

In this situation, we can use the technique described by Harms[13,20,23], using a fixation system with screws on C1 lateral masses connected by means of nails to screws inserted on C2 pedicle. In this technique, there is a potential to reduce the sub-dislocation, and, in most cases, inserting the screw on C2 pedicle is possible, because it presents a more medial and inferior position to the transarticular screw in the technique described by Magerl.[13-15] Several studies report few little problems in inserting screws on C1 lateral mass, as in the technique by Harms[24-26], but some patients have a C2 pedicle not enabling screws to be passed through[22,24-27] due to the same changes described for Magerl's technique.

Wright et al.[28] developed a fixation technique between C1 and C2 using bilateral screws on C1 lateral mass and on C2 laminae, connected by nails. In a series of 10 cases, a low complication rate and an appropriate stability of the fixated segment are reported. These good results have been attributed to a reduced risk of iatrogenic injuries when inserting screws, since the insertion sites are not so close to vascular or neural structures.[20-22,24-28]

The biomechanical resistance in the technique by Wright was reported in a study with anatomical cadaver pieces, showing high synthesis stability.[20]

Wright et al.[23] and Cassinelli et al.[29] in anatomical studies with dried cadaver bones showed the feasibility of inserting screws on C2 laminae. Cassinelli et al.[29] in their study on 420 dried cadaver bones found a mean laminar thickness of 5.7 mm, 70.5% of which presenting thickness above or equal to 5 mm, 92.6% above or equal to 4 mm, and 96.7% above or equal to 3.5 mm, which is consistent to our study data, where the mean external thickness measurements of the mid laminar portions was 5.83 mm, with 76.78% showing thickness above or equal to 5 mm, 91.07% above or equal to 4 mm, and 91.07% above or equal to 3.5 mm. This small percentage variation is probably due to a reduced number of anatomical pieces.

CONCLUSION

Our study corroborates the conclusion of previous studies, showing the feasibility of inserting intralaminar screws on C2 vertebra.

As we detected 8.93% of specimens with external laminar thickness below 3.5 mm (diameter of screws usually employed), we suggest that a preoperative tomographic study is conducted for identifying patients at higher surgical risk.

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