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CORRELATION OF CRANIOVERTEBRAL PARAMETERS WITH THE RETROPHARYNGEAL SPACE IN POSTERIOR C1-C2 ARTHRODESIS

CORRELAÇÃO DOS PARÂMETROS CRANIOVERTEBRAL COM O ESPAÇO RETROFARÍNGEO NA ARTRODESE POSTERIOR C1-C2

CORRELACIÓN DE LOS PARÁMETROS CRANEOVERTEBRAL CON EL ESPACIO RETROFARÍNGEO EN LA ARTRODESIS POSTERIOR C1-C2

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ABSTRACT

Introduction/Objective: The craniovertebral junction (CVJ) requires a detailed evaluation, as the changes in alignment caused by surgery can affect adjacent structures in a secondary way. Examples of these effects are dyspnea or dysphagia after posterior occipitocervical arthrodesis, due to decreased caliber of the oropharynx. These changes can be identified perioperatively by several radiographic parameters that aim to predict possible postoperative respiratory complications. Such complications appear to be related to the narrowest oropharyngeal airway space (nPAS), and may also occur following atlantoaxial (C1-C2) arthrodesis. This work aims to correlate the variation in CVJ alignment parameters before and after C1-C2 arthrodesis with the variation in nPAS. Methods: Patients who underwent posterior C1-C2 arthrodesis between 2011 and 2019 at the National Institute of Traumatology and Orthopedics (INTO) were included in the study, totaling 26 patients. The parameters evaluated included cervical lordosis, C1-C2 angle, slope of C2, Occipito-C2 angle (O-C2), pharyngeal inlet angle (PIA), pharyngeal tilt angle (PTA), occiput and external acoustic meatus to axis angle (O-EAa), cranial transverse motion against C2 angle (C2TA), axial tilt (AT) and the percentage of change in nPAS (%ΔnPAS). Result: A correlation was observed between the change in C1-C2 angle, O-C2, PTA, C2TA and the %ΔnPAS. Conclusion: The change in cervical alignment and CVJ parameters is correlated with %ΔnPAS and should, therefore, be evaluated before and after atlantoaxial fusion as a means of predicting a possible respiratory complication. ***Level of Evidence: III; Cross sectional study.***

Keywords: Dyspnea; Deglutition Disorders; Arthrodesis; Atlanto -Axial Joint; Cervical Vertebral.

RESUMO

Introdução/Objetivo: A junção craniovertebral (JCV) deve ter avaliação detalhada já que as alterações de alinhamento ocasionadas pela cirurgia podem acometer estruturas adjacentes de forma secundária. Exemplos desses efeitos são dispneia ou disfagia depois de artrodese occipitocervical posterior, por diminuição no calibre da orofaringe. Essas alterações podem ser identificadas no perioperatório por diversos parâmetros radiográficos que visam predizer possíveis complicações respiratórias pós-operatórias. Tais complicações parecem estar relacionadas com o menor espaço da via orofaríngea (nPAS, narrowest oropharyngeal airway space) e também podem ocorrer depois de artrodese atlantoaxial (C1-C2). Este trabalho tem como objetivo correlacionar a variação dos parâmetros de alinhamento da JCV no pré e pós-operatório de artrodese C1-C2 com a variação do nPAS. Métodos: Foram incluídos no estudo pacientes submetidos à artrodese posterior C1-C2 entre 2011 e 2019 no Instituto Nacional de Traumatologia e Ortopedia (INTO), totalizando 26 indivíduos. Os parâmetros avaliados incluíram lordose cervical, ângulo C1-C2, inclinação de C2, ângulo Occipito-C2 (O-C2), ângulo de entrada da faringe (PIA, pharyngeal inlet angle), ângulo de inclinação da faringe (PTA, pharyngeal tilt angle), ângulo do eixo occipital e meato acústico externo (O-EAa, occiput and external acoustic meatus to axis angle), movimento transversal craniano contra o ângulo C2 (C2TA, cranial transverse motion against C2 angle), inclinação axial (AT, axial tilt) e porcentagem de mudança no nPAS (%ΔnPAS) resultado: Foi observada correlação entre a mudança dos ângulos C1-C2, OC2, PTA, C2TA e a %ΔnPAS. Conclusão: A alteração do alinhamento cervical e dos parâmetros da JCV está correlacionada com a %ΔnPAS e deve, portanto, ser avaliada antes e depois da artrodese atlantoaxial como forma de prever uma possível complicação respiratória. ***Nível de Evidência III; Estudo transversal.***

Descritores: *Dispneia; Transtornos de Deglutição; Artrodese; Articulação Athantoaxial; Vértebras Cervicais.*

RESUMEN

Introducción/Objetivo: La unión craneocervical debe ser objeto de una evaluación detallada, ya que los cambios de alineación provocados por la cirugía pueden afectar de forma secundaria a las estructuras adyacentes. Ejemplos de estos efectos son la disnea o la disfagia después de la artrodesis occipitocervical posterior debido a la disminución del calibre de la orofaringe. Estos cambios pueden identificarse en el período perioperatorio por varios parámetros radiográficos que pretenden predecir posibles complicaciones respiratorias

Study conducted at the Spine Disease Center at the National Institute of Traumatology and Orthopedics (INTO), Rio de Janeiro, RJ, Brazil.
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postoperatorias. Estas complicaciones parecen estar relacionadas con el espacio orofaríngeo más estrecho (nPAS*, narrowest oropharyngeal airway space) y también pueden producirse tras la artrodesis atlantoaxial (C1-C2). Este trabajo tiene como objetivo correlacionar la variación de los parámetros de alineación de la unión craneocervical en el período pre y postoperatorio de la artrodesis C1-C2 con la variación del nPAS. Métodos: Se incluyeron en el estudio los pacientes sometidos a artrodesis posterior C1-C2 entre 2011 y 2019 en el Instituto Nacional de Traumatología y Ortopedia (INTO), totalizando 26 individuos. Los parámetros evaluados incluyeron lordosis cervical, ángulo C1-C2, inclinación de C2, ángulo Occipito-C2 (O-C2), ángulo de entrada de la faringe (PIA, pharyngeal inlet angle), , ángulo de inclinación de la faringe (PTA, pharyngeal tilt angle)),* ángulo del eje occipital y el meato acústico *externo (O-EAa, occiput and external acoustic meatus to axis angle), movimiento transversal craneal contra el ángulo C2 (C2TA, cranial transverse motion against C2 angle), inclinación axial (AT, axial tilt)) y porcentaje de cambio en el nPAS (%ΔnPAS). Resultado: Se observó una correlación entre el cambio de los* ángulos *C1-C2, O-C2, PTA, C2TA y %ΔnPAS. Conclusión: El cambio en la alineación cervical y los parámetros de la unión craneovertebral se correlaciona con el %ΔnPAS y por lo tanto, debe evaluarse antes y después de la artrodesis atlantoaxial como forma de predecir una posible complicación respiratoria.* ***Nivel de Evidencia III; Estudio transversal.***

Descriptores: *Disnea; Trastornos de Deglución; Artrodesis; Articulación Atlantoaxodia; Vértebras Cervicales.*

INTRODUCTION

The craniovertebral junction is a complex region that involves the occiput, the atlas, the axis and its capsuloligamentous components. These bones are closely related to important cervical structures, such as the vertebral artery and the oropharynx, which must be evaluated during surgical planning. This evaluation should include the possibility of direct or indirect influence, since changes in alignment caused by a surgical approach to the upper cervical spine may affect these adjacent structures in a secondary manner.[1-3]

In the literature, one of the most prevalent complications is dysphagia following posterior occipitocervical arthrodesis, due to a decrease in the caliber of the oropharynx. Dysphagia can affect 15.8% to 26.3% of the patients who undergo surgery.[4] The hypothesis for this type of occurrence is that the fixation of the craniovertebral junction in a less lordotic position than the preoperative one causes a rotation of the maxilla with consequent posterior displacement of the mandible, resulting in oropharyngeal stenosis. Head position also influences the tonic reflexes of the neck, and muscle length, altering the activity of the genioglossus muscle, and patients in a more kyphotic position may also suffer suprahyoid muscle contractures, causing swallowing impairment.[5] These changes can be identified in the perioperative period by several radiographic parameters that aim to predict a possible obstructive complication in the postoperative period, based on their relationship with the narrowest oropharyngeal airway space (nPAS) – anteroposterior distance of the oropharyngeal region in its narrowest portion seen on the lateral radiograph of the cervical spine, between the uvula and the epiglottis, which is closely correlated with swallowing function. The variation in occipito-C2 angle (OC2) is the most frequently mentioned parameter, and has a linear correlation with the percentage change of the narrowest oropharyngeal airway space (%ΔnPAS).[1-3]

Another morbidity associated with this procedure is the restriction of the patient's craniocervical flexion-extension, hindering his/her daily activities. Evaluating this aspect, Goel et al. proposed that craniocervical junction instability is usually concentrated in the atlantoaxial joint, therefore, only atlantoaxial arthrodesis would be sufficient for effective treatment.[6] Nevertheless, it should be remembered that this instability is closely associated with atlas assimilation, since this vertebra has the same embryological origin as the atlantoaxial ligaments,[7] thus directly altering the occipitocervical alignment and restricting the flexion-extension of this region. This occurs even when the occiput (C0) is not included, as in case of treatment with the Goel/Harms technique.[8] It is known that this technique is also associated with postoperative dysphagia; however, there are still no studies that evaluate this complication in these cases.

Given the above, this study aims to correlate the changes in alignment parameters of the cervical spine and craniovertebral junction before and after atlantoaxial fusion by the Goel/Harms technique, with the percentage variation in nPAS.

METHODS

Patients who underwent posterior C1-C2 arthrodesis between 2011 and 2019 at the National Institute of Traumatology and Orthopedics (INTO) were included in the study, totaling 40 cases. Those whose radiographs did not allow the proposed measurements to be taken, or whose arthrodesis included other levels, were excluded. Thus, a total of 26 patients were included in the study and their medical records were retrospectively analyzed. This study was approval by the INTO ethics committee (CAAE: 21225019.0.0000.5273). The radiographic analyses were performed using the software program *Surgimap®*.

The statistical analysis was performed using the software program R®, version 4.0.2. Multiple linear regression was performed by correlating the variation in radiographic parameters and the percentage variation in nPAS.

Radiographic Parameters

The variation in the following preoperative and postoperative parameters was evaluated: C1-C2 angle, C2-C7 angle, C2 slope (CS), occipito-C2 angle (OC2), pharyngeal inlet angle (PIA), pharyngeal tilt angle (PTA), occiput and external acoustic meatus to axis angle (O-EAa), cranial transverse motion against c2 angle (C2TA), axial tilt (AT) and the percentage change of the narrowest oropharyngeal airway space (%ΔnPAS). Some parameters used the McGregor line[9] and the Chamberlain line[10] for the measurements. The McGregor line is drawn from the hard palate to the most caudal point of the occipital bone, and the Chamberlain line is drawn from the hard palate to the posterior margin of the foramen magnum, both on lateral radiographs of the cervical spine.

The C1-C2 angle is the angle between a line tangent inferiorly to the C1 arch and a line tangent to the inferior endplate of C2. The C2-C7 angle (cervical lordosis) is measured using the modified Cobb method, starting with the identification of the inferior endplate of C2 and C7 and drawing a line tangent to these references. Subsequently, a line perpendicular to each of them is drawn, and the acute angle formed between them is the C2-C7 angle. The C2 slope is measured by the angle formed between a line tangent to the inferior endplate of C2 and a horizontal reference line. The pharyngeal inlet angle is measured between the McGregor line and the line joining the center of the anterior C1 arch and the apex of the cervical lordosis. Finally, the pharyngeal tilt angle is measured between the McGregor line and a line that runs from the C2 pedicle to the center of the body of the vertebra to the apex of the cervical lordosis (Figure 1A).

The occipito-C2 angle is measured between the McGregor line, which is more easily identified on radiographs, and a line tangent to the inferior endplate of C2. The occiput and external acoustic meatus to the axis angle was measured between the McGregor line and the line that runs from the center of the external acoustic meatus (or the center of a line that joins the two meatus) to the midpoint of the inferior endplate of C2. The cranial transverse motion against the c2 angle was measured between the line that runs from the center of the external acoustic meatus (or from the center of a line that joins the two meatus) to the midpoint of the inferior endplate of C2 and the line tangent to the inferior endplate of C2. The axial tilt was measured between the Chamberlain line and a tangent line posteriorly to the C2 body and the odontoid process (Figure 1B).

The narrowest oropharyngeal airway space (nPAS) was obtained by transversely measuring the hypopharynx in its narrowest portion between the uvula and the epiglottis (Figure 2). As the percentage change of the narrowest oropharyngeal airway space, it was obtained by means of the following formula:

%ΔnPAS = (postoperative nPAS – preoperative nPAS)/ preoperative nPAS x 100.

RESULTS

After applying the inclusion and exclusion criteria, 26 patients were selected for analysis, with an average age of 40.34 years. The most common diagnosis among these individuals was basilar invagination.

The general clinical-surgical features of the patients are summarized in Table 1.

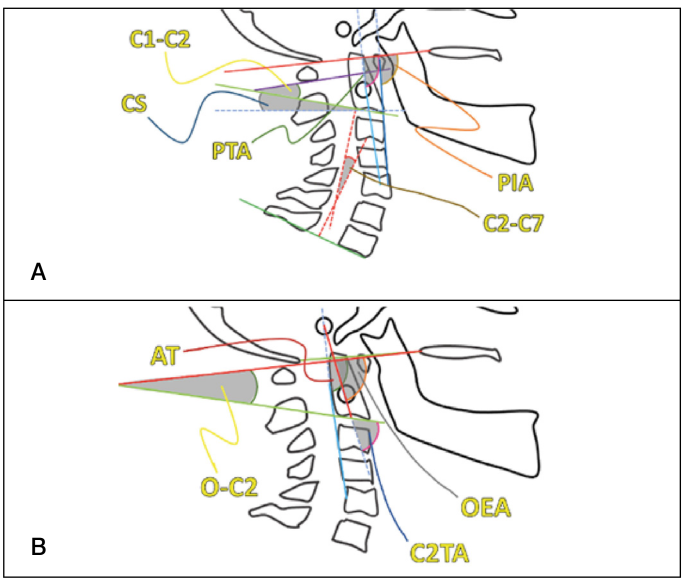

Figure 1. Radiographic Parameters: A – C1-C2: C1-C2 angle; C2-C7: Cervical Lordosis; CS: C2 slope; PIA: Pharyngeal inlet angle; PTA: Pharyngeal tilt angle/ B – OC2: occipito-C2 angle; O-EAa: occiput and external acoustic meatus to axis angle; C2TA: cranial transverse motion against c2; AT: axial tilt.

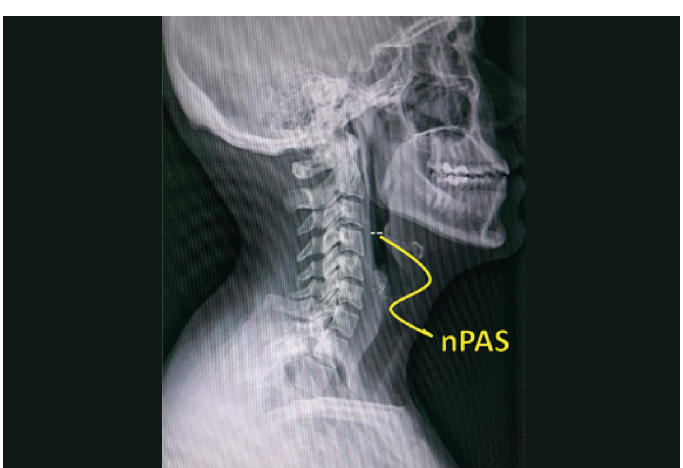

Figure 2. Measurement of the narrowest oropharyngeal airway space (nPAS) on a lateral radiography of the cervical spine.

The investigation of associated factors was carried out using multiple linear regression variables.

Only the variation of C1-C2, OC2, PTA and C2TA showed a statistically significant correlation with %ΔnPAS (Table 2).

ΔC1-C2: C1-C2 angle variation; ΔC2-C7: Cervical Lordosis variation; ΔCS: C2 slope variation; ΔOC2: occipito-C2 angle variation; ΔPIA: Pharyngeal inlet angle variation; ΔPTA: Pharyngeal tilt angle variation; ΔO-EAa: occiput and external acoustic meatus to axis angle variation; ΔC2TA: cranial transverse motion against c2 variation; ΔAT: axial tilt variation.

The chart below (Figure 3) shows that the Gauss-Markov condition is being met, as no apparent pattern is occurring, i.e., the variance is constant, and the behavior of the residuals is around the average, i.e., equal to 0.

Through graphical analysis (Figure 4) and through the Shapiro--Wilk test (Value - p = 0.090), attributing a significance level of 5%, it is possible to obtain statistical evidence that the residuals have a normal distribution.

DISCUSSION

Classically, surgical stabilization of the craniovertebral junction is performed with posterior occipitocervical fusion. This method has some inherent morbidities, including the loss of 50% of craniocervical flexion and 50% of cervical rotation. Other effects include dysphagia and dyspnea, due to a secondary decrease in the oropharynx

Table 1. General clinical-surgical features.

Feature	Absolute number	Percentage
Sex		
Male	14	54%
Female	12	46%
Diagnosis		
Basilar invagination	18	69%
Grisel syndrome	3	11%
Odontoid fracture	2	8%
Type 1 Chiari malformation	1	4%
C1-C2 spondylodiscitis	1	4%
Atlas fracture	1	4%
ASIA classification		
E	14	54%
D	9	35%
C	3	11%
B	0	0%
A	0	0%
Type of Surgery		
Isolated C1-C2 fusion	8	31%
Distraction + C1-C2 fusion	18	69%

ASIA - American Spinal Injury Association; Isolated C1-C2 fusion – Harms technique; Distraction + C1-C2 fusion – Goel technique.

Table 2. Result of regression analysis.

Regression analysis of %ΔnPAS with radiographic variables					
Regressive variables	Non-standardized coefficient		t	p-value	VIF
	B	Standard error			
Constant	-0.75	0.25	-3.02	0.017	
ΔC1-C2	0.01	0.01	2.49	0.037	6.86
ΔC2-C7	0.00	0.00	-1.11	0.301	4.98
ΔCS	0.01	0.00	1.44	0.188	4.43
ΔOC2	0.05	0.02	2.40	0.043	66.54
ΔPIA	0.01	0.01	0.92	0.385	17.40
ΔPTA	0.03	0.01	4.43	0.002	6.70
ΔO-EAa	-0.03	0.02	-1.85	0.102	36.42
ΔC2TA	0.03	0.01	2.49	0.037	25.84
ΔAT	-0.02	0.01	-1.78	0.112	23.74

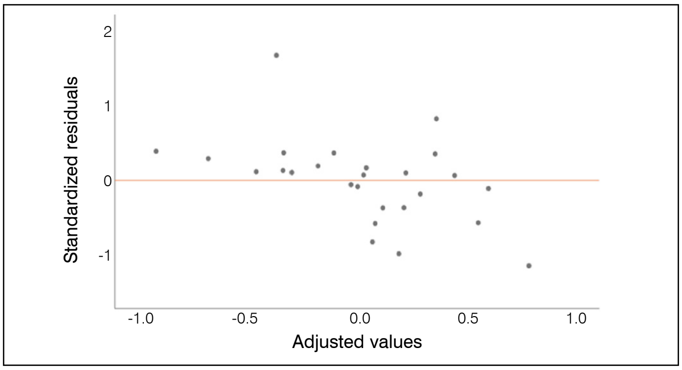

Figure 3. Scatter plot of standardized residuals versus adjusted values.

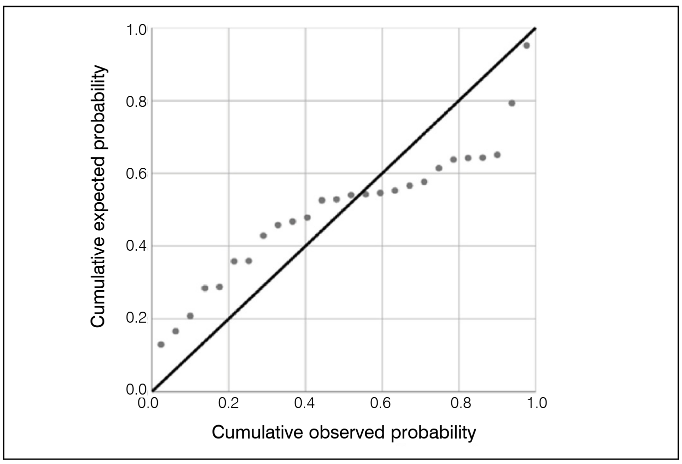

Figure 4. Normal probability distribution.

caliber, whether due to edema or to changes in the cervical or craniovertebral alignment, sometimes with devastating outcomes.[11]

Maintaining mobility is one of the benefits of preserving the occiput by performing only atlantoaxial fusion surgery, even facilitating swallowing by maintaining the C0-C1 dynamic compensation mechanism. However, even when the occiput is not included, and arthrodesis of only C1-C2 is performed by the Goel/Harms method, obstructive symptoms can still occur, decreasing the patient's quality of life. Examples are that the patient may require changes in positioning, the use of a continuous positive airway pressure device when sleeping, or changes to the consistency of foods to improve swallowing.[11,12] Nevertheless, it should be remembered that atlantoaxial instability is closely associated with atlas assimilation, since this vertebra has the same embryological origin as the atlantoaxial ligaments,[7] with the same implications as an occipitocervical instrumentation, even when C0 is not included, a fact observed in 69% of our sample.

In order to avoid this atlantoaxial instability, parameters must be used that evaluate the diameter of the oropharynx after the final positioning of the arthrodesis. Direct evaluation is ideal; but in the intraoperative period, this is technically very difficult due to the interposition of structures around the pharynx. Therefore, parameters must be used that correlate with %ΔnPAS to predict the oropharyngeal space at the end of the procedure.

Several parameters have already been described in the literature for this purpose. The most commonly mentioned one is the OC2 angle.[3,5,13] Decreases in this angle of 5° to 10° in relation to the preoperative period can lead to obstructive complications.[14,15] In our sample, this angle had good statistical correlation ($p = 0.043$) with %ΔnPAS. However, it should be remembered that this can be modified by changes in the C2 endplate,[16] whether congenital or acquired, and some studies did not show good correlation with %ΔnPAS.[17,18] Such studies include, for example, those that evaluated the treatment of atlantoaxial dislocation. Another factor that can reduce the nPAS index is the reduction in C1-C2 dislocation, because it entails posterior translation of the skull, despite the increase in the OC2 angle.[5] This translation can be measured by O-EAa and C2TA, which use the external auditory meatus as a reference. These seem to correlate well with %ΔnPAS,[4,19] and are easier to measure compared to the OC2 angle. In our study, only C2TA was shown to have a statistically significant correlation ($p = 0.037$) with %ΔnPAS after multiple linear regression analysis. The O-EAa also has the advantage that it is not influenced by morphological changes in the C2 endplate, as it does not involve this endplate in the measurement. However, it is known that the external auditory meatus is also a difficult parameter to identify on lateral radiographs of the cervical spine.[20]

In addition to the edema and mandibular movements caused by an increase in craniovertebral kyphosis, reciprocal changes in the subaxial cervical spine also appear to be involved in the genesis of the oropharyngeal narrowing, since the reciprocal increase in cervical lordosis can create anterior compression on the hypopharynx (Figure 5). Based on this, some parameters were described linking the alignment of the subaxial cervical spine to obstructive symptoms, such as PIA and PTA.[17,18] PTA must be equal to or greater than 77° to avoid obstructive complications, whereas the PIA must be equal to or greater than 90°.[21] In our case, only PTA had a statistically significant correlation ($p=0.002$) with %ΔnPAS. Despite all these warnings, one must always remember that while fixation of the craniocervical junction in a more kyphotic position can lead to complications, fixation in hyperextension can also lead to kyphosis and degenerative disease of the subaxial cervical spine in the long term.[22]

This study has some limitations. It is known that breathing and swallowing involve a dynamic process and are, therefore, difficult to evaluate using static measurements such as nPAS. Many factors, including organic and functional disorders, can cause dyspnea and/or dysphagia. Measurements were performed using standard software, but it is known that these measurements have large inter- and intra-observer variability, due to the difficulty of measuring the parameters of each of these angles. Another form of measurement described in the literature is intraoperative computed tomography, always attempting to keep the craniocervical junction in a neutral or more extended position in relation to

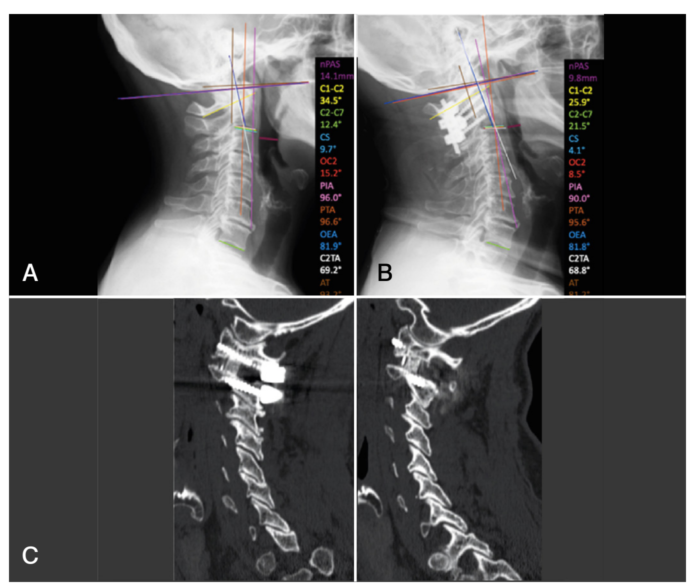

Figure 5. A - Female patient, with basilar invagination, with preoperative measurements. B - Postoperative measurements after treatment with the C1-C2 distraction arthrodesis technique, a decrease in craniocervical lordosis parameters (C1-C2, OC2, PTA and C2TA) and a reciprocal increase in subaxial cervical lordosis with consequent decrease in nPAS. C – Postoperative Computed Tomography in sagittal reconstruction showing distraction in C1-C2 joint with cages.

the preoperative period. This prevents atlantoaxial fixation from occurring in a cervical retraction position (˜military tuck˜), which is sometimes used to facilitate surgical access and C1-C2 reduction, thus avoiding obstructive complications.[23] In our sample, only 5 patients evolved with dysphagia and 2 patients with dyspnea in the postoperative period, probably due to the small size of the sample. Thus, a prospective study with a larger number of patients is needed, to confirm the correlations described here, including their clinical manifestations.

CONCLUSION

The changes in C1-C2, OC2, PTA and C2TA showed a statistical correlation with %ΔnPAS in atlantoaxial fusion surgeries and should, therefore, be evaluated during surgery to predict a possible obstructive complication.

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

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