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Cone Beam Computed Tomography Analysis of Upper Airway Measurements in Patients with Cervical Spine Pathology – Secondary data analysis

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Abstract:
Background*: The upper airway's integrity and patency are ensured by the bony and cartilaginous structures covering the naso- and oropharynx. The cervical spine plays a crucial role in maintaining upper airway patency because of its anatomical relationship to the pharynx. Pathological changes in the cervical spine were reported to influence the upper airway. These cervical spine changes are often overlooked in CBCT scans, as the purpose of taking the scan is different. Many of the cervical spine disorders are known to be related to the development of orofacial pain, obstructive sleep apnoea and restriction in the upper airway. In this study, the correlation between cervical spine disorders seen in CBCT scans and their upper airway volume is assessed. Three- dimensional airway volume, minimum cross-sectional area and location of minimum cross-sectional area are measured in both patients with cervical spine disorder and in normal control groups*
Materials and Methods*: The study included sixty-eight CBCT scans, equally divided into two groups: those with and without cervical spine pathologies (test and control groups). The three-dimensional upper airway volume, area, and area of minimum cross-section were calculated for both groups using Dolphin Imaging software 11.95. Categorical variables were expressed as frequency and percentage. Continuous variables were presented by mean±SD or median(Q1-Q3). To test the statistical significance of the difference in gender between groups, the Chi-square test was used. To test the statistical significance of the difference in the mean or median of continuous variables between groups, an independent sample t-test for age and for other skewed data, the Mann-Whitney U test was used.*
Results*: The mean age of the test group was considerably greater than that of the control group, and there was no significant gender difference seen. Median upper airway area and volume were smaller in cervical spine patients but the difference was not statistically significant. In comparison to the control group, median of the minimum cross-sectional area in test group [120(81-211)mm^2] was significantly smaller (p-value<0.05). In test group, the minimum cross-sectional area was less than 110mm^2 in 19(55.8%) patients.*
Conclusion: *The minimum constricted area in upper airway was significantly less in patients with cervical spine pathology compared to normal control group showing an increased risk of OSA in patients with cervical spine changes.*
Key Word*: Cervical spine, Cone Beam CT, Obstructive sleep apnea, Airway*

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I. Introduction

Radiographic evaluation of the upper airway is always needed to identify anatomical obstructions in the pharyngeal space and to assess how well orthodontic and surgical treatments work for people with sleep-related disorders. The upper airway has been previously assessed with lateral cephalograms. The established use of Cone Beam Computed Tomography (CBCT), and its three-dimensional anatomical visualization in 1:1 proportion expanded its application to the evaluation of the upper airway three dimensionally including its volume, area, and areas of constriction. [1] , [2] The ability to locate and measure the minimum cross-sectional area of the upper airway in CBCT aids in recognizing patients at heightened risk of obstructive sleep apnea (OSA).

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The upper airway's integrity and patency are ensured by the bony and cartilaginous structures covering the naso- and oropharynx. The cervical spine plays a crucial role in maintaining upper airway patency because of its anatomical relationship to the pharynx. Pathological changes in the cervical spine were reported to influence the upper airway. Sonnesen et al demonstrated the association of OSA and cervical body fusion, craniofacial morphologies, and head and neck posture in their study. [5],[6] It has been reported that cervical spine pathologic changes like Diffuse idiopathic skeletal hyperostosis (DISH) can lead to anatomical obstruction of the airway and dysphagia. [7] Increased prevalence of cervical spine pathologies like osteochondromas, ligament calcifications, rheumatoid arthritis, etc were reported in patients with OSA.[8] Cervical spine fusions and other abnormalities that reduce retropharyngeal space are linked with OSA, likely by way of worsening posture and reducing range of motion thereby worsening temporomandibular disorder and orofacial pain. [9]

However, these cervical spine changes are often overlooked in CBCT scans as the primary purpose of taking the scan is different. Previously reported studies assessed the cervical spine and airway in known obstructive sleep apnea patients. In this study, Cone Beam CT scans were evaluated for a period of time, dividing the sample into those with and without cervical spine changes. The three-dimensional upper airway volume, area, and minimum cross-sectional area were measured in both groups to assess the relationship between upper airway dimensions and cervical spine pathology.

II. Material And Methods

Study Participants: The study was done as a single institutional study in Amrita School of Dentistry, Kochi, India where the Cone-beam CT scan of patients from January 2024 to June 2024 was retrospectively collected and analyzed. CBCT scans were assessed by a maxillofacial radiologist for pathological changes in cervical vertebrae and divided the sample into two groups - those with and without cervical spine pathology (i.e., the test group and control group) respectively.

Inclusion criteria

The CBCT(17*13.5 full FOV) scans taken in maximum intercuspal position and with a straight posture and natural head position were included. Adult patients greater than 18 years of age were included irrespective of gender.

Exclusion criteria

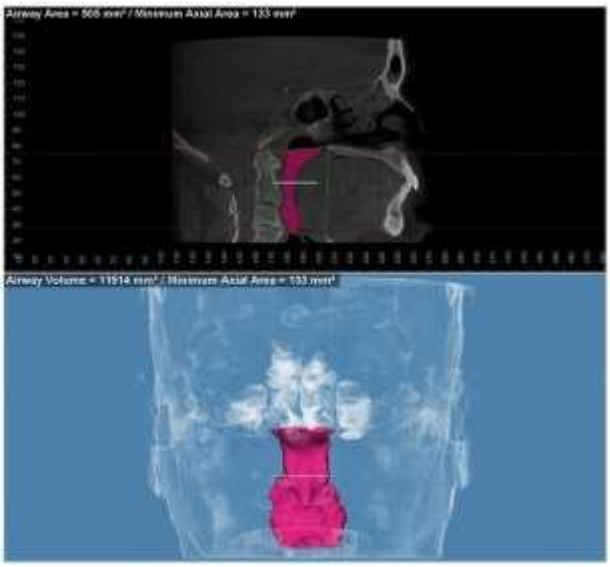
Cone beam CT scans of patients taken not in intercuspal position, improper head positioning and posture, scans not completely covering the area of interest (upper pharyngeal airway), and scans of patients who had undergone any oropharyngeal surgical procedures and maxillofacial trauma cases were not included.

The test group consists of 34 adult patients with any cervical spine pathologies noticed while evaluating the CBCT scan. The control group consists of 34 adult patients without any cervical spine pathologies seen in CBCT scan.

CBCT Scan parameters: Kodak C S 9300 3-D was used for obtaining CBCT scan of the patients with a Field of View of 17×13.5, exposure of 5 mA, 90 kVp, 11.26 seconds, 300 µm × 300 µm × 300 µm voxel size and radiation dose of 1981 mGy/cm^2.

Airway measurements: Dolphin Imaging software 11.95 was used for measuring three-dimensional upper airway volume, area and minimum cross-sectional area with superior limit of odontoid process of C2, posterior nasal spine, antero-inferior point of C3 vertebrae, anterior limit of hyoid, and inferior point of uvula as landmarks in the midsagittal plane for ensuring reproducibility. (Figure 1) The airway dimensions between the test and control groups were compared to check whether any relationship exists between the reduction in upper airway dimensions and cervical spine pathology.

Figure 1 – Three-dimensional upper airway evaluation in Cone Beam CT scan was done using Dolphin Imaging software 11.95 – Upper airway volume, airway area and minimum cross-sectional area were recorded.



Statistical analysis

IBM SPSS version 20.0 was used for statistical analysis. Categorical variables were expressed as frequency and percentage. Continuous variables were presented by mean ± SD or median (Q1-Q3). To test the statistical significance of the difference in the gender between groups, the Chi-square test was used. To test the statistical significance of the difference in the mean or median of continuous variables between groups, an independent sample t-test for age and for other skewed data Mann Whitney U test was used.

III. Result

Study population : The total sample included 68 patients, divided into two groups – a test group with 34 patients with cervical spine pathology and a control group with 34 patients without any cervical pathology. The mean age of the 23 females and 11 males in test group was 33.7±13.5 years. The mean age of the 25 females and 9 males in the control group was 33.74 ± 13.51. The mean age of the patient in the test group was greater than that of the control group and this difference was statistically significant (p< 0.001) (Table 1). Statistically, no difference in gender between the groups was seen (table 2).

Table no 1: Comparison of age between groups

Group	N	Mean	Std. Deviation	p-value		Group
Age	Test	34	53.79	13.36	<0.001	Age
	Control	34	33.74	13.51		
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Age	Test	34	53.79	13.36	<0.001	Age

	Control	34	33.74	13.51		

Table no 2: Comparison of gender between two groups

Gender	Group		p-value
	Test	control	
	n= 34%	n=34%	
Female	23(67.6)	25 (73.5)	0.6
Male	11(32.4)	9 (26.5)	

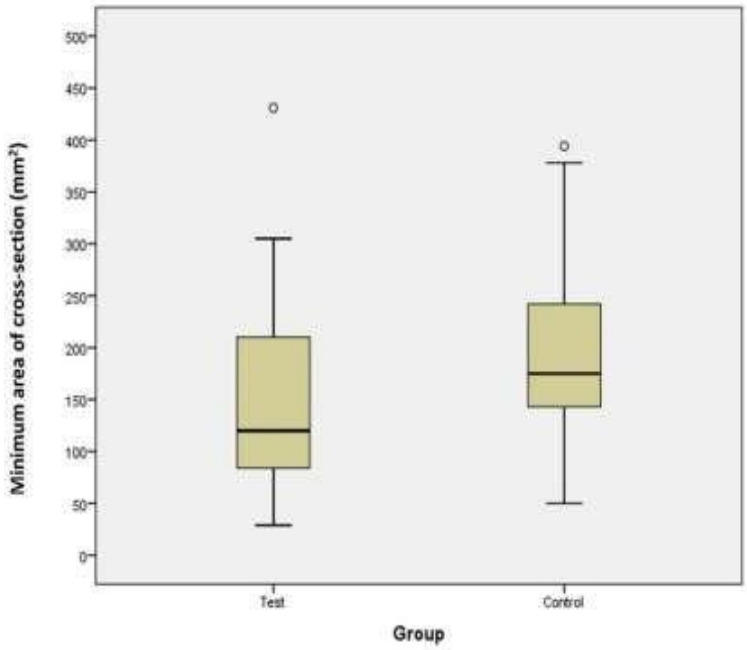
Airway measurements: The median (Q1-Q3) of the upper airway volume of the test group was 10755(8840-17298), and that of the control group was 13878(10799-17796). The median (Q1-Q3) of the upper airway area of the test group was 498.5(407-637), and that of the control group was 579.5(492-703). Comparing the test group to the control group, there was a decrease in the median upper airway volume and area in the test group. P-value > 0.05 indicated that the outcome was not statistically significant. (Table 3)

Table 3: Comparison of airway measurements between groups

Variables	group	n	Median (Q1-Q3)	p-value
Upper airway volume (mm^3)	test	34	10755 (8840-17298	0.119
	control	34	13878(10799-17796)	
Upper airway area (mm^2)	test	34	498.5(407-637)	0.61
	control	34	579.5(492-703)	
Minimum area of cross-section (mm^2)	test	34	120(81-211)	0.021
	control	34	175(138-242)	

The median (Q1-Q3) of the minimum area of the cross-section of the test group was 120(81-211), and that of the control group was 175(138-242). In comparison to the control group, the test group's median cross-sectional area was smaller. A statistically significant result was obtained (p-value < 0.05). (Figure 2)

Figure 2 - Difference in median of minimum area of cross-section in test group with cervical spine pathology and control group without cervical spine changes. The minimum cross-sectional area was less in the test group compared to the control group (p<0.01)



Frequency of cervical spine pathology in test group: In 34 patients with cervical spine changes noticed in cone beam CT, the most common finding was osteophyte seen in 27 (79%) patients, followed by Cervical ligament calcification/ossification (26%), sclerotic changes (20%), erosion (8.8 %), decreased intervertebral space (8.8%), malalignment of cervical vertebrae (rotated C1, C2) (5.9%) and partial fusion (2.9%). (Table 4)

Table 4 : Frequency of cervical spine pathologies in the test group

Cervical spine pathology	**Frequency – N (%)**
Osteophyte	27 (79%)
Cervical ligament calcification/ossification	9 (26%)
Sclerosis	7 (20%)
Erosion	3 (8.8%)
Decreased intervertebral space	3 (8.8%)
Malalignment (C1, C2 rotation)	2 (5.9%)
Partial fusion	1 (2.9 %)

IV. Discussion

The study included 68 cone beam CT scans of patients, divided into two groups (test and control group), each group consisted of 34 patients with and without cervical spine pathologies. The test group included 23 females and 11 males with a mean age of 53.79±13.36, while the control group had 25 females and 9 males with a mean age of 33.74 ±13.51. The test group's mean age was significantly higher than the control group's, and there was no appreciable gender difference between the two. In the test group with cervical spine changes, the common pathology noticed was degenerative changes with osteophyte in 79% of scans, followed by Cervical ligament calcification/ossification (26%), sclerotic changes (20%), erosion (8.8 %) and decreased intervertebral space (8.8%). Rotation of C1 and C2 was seen in 2 patients and partial fusion of C3 and C4 in 1 patient. These findings were comparable to the results shown by Alsufyani et al (10) , where they described incidental findings in the cervical spine and clivus in 732 cone beam CT scans. Among which the most common findings were in the cervical spine with 78.7% degenerative changes, with no gender difference and significantly seen in patients older than 50 years. Anteriorly protruding osteophytes were reported to cause difficulty in deglutition and breathing by Tanabe et al. (11)

Dolphin Imaging software 11.95 was used to obtain the upper airway dimensions in both groups. The median upper airway area and volume were smaller in cervical spine patients than that of the normal control group but the difference was not statistically significant.

The median (Q1-Q3) of the minimum area of the cross-section of the test group was 120 (81-211) mm^2 and that of the control group was 175(138-242) mm^2. In comparison to the control group, median of the minimum cross-sectional area in the test group was significantly smaller (p-value < 0.05). In 34 patients with cervical spine changes, the minimum cross-sectional area was less than 110 mm^2 in 19 (55.8%) patients.

Steffy et al (4) divided the OSA severity based on the radiographic finding of the minimum area of cross-section. Upper airway cross-sectional area less than 52 mm^2 was considered as high risk, 52 mm^2 to 100 mm^2 as intermediate risk, and more than 110 mm^2 as low risk for OSA based on cone Beam CT scan findings. Only a few studies in the literature investigated both cervical spine morphology and sleep apnea. Sonnesen et al (6) reported morphological changes like cervical spine fusion (21.1%) and posterior arch deficiency (14%) in CBCT scans of patients with OSA. In our study, partial fusion of cervical vertebrae was seen only in one patient. Ando et al (12) assessed cervical spine osteophytes and Nuchal ligament calcification in patients with OSA and Snoring. They showed a significant association between nuchal ligament calcification and OSA, and no significant association between osteophytes and OSA severity. Even though there is a lack of literature showing the association between the severity of OSA and cervical spine changes, cervical spine pathologies like DISH were well known to cause dysphagia and difficulty in deglutition. Anteriorly protruding osteophytes were reported to cause difficulty in intubation of unconscious patients.

(13) Sun et al reported two cases of OSA caused by cervical spondylosis and osteophyte causing compression on the anterior pharyngeal wall. (14)

In our study, in the test group with cervical spine changes, 55% of patients had an airway less than 110 mm^2, at risk of developing OSA. So careful evaluation of these changes in cone beam CT scan can help

diagnose such disorders early and refer the patient if needed. Along with that, in case of reduced airway, to maintain airway patency patients acquire a forward head posture which can also worsen the existing cervical spine pathologies due to extra load on the cervical region. Also, these cervical spine degenerative changes are linked with degenerative changes in the temporomandibular joint and chronic orofacial pain. (15) These findings outweigh the need for maxillofacial radiologists to carefully monitor the cervical spine region while interpreting the scans, as these regions often go undiagnosed due to their complex anatomy and as they are not in the region of interest for the purpose for which the scan was taken.

Our study had some limitations of restricted sample size, and clinical characteristics of patients were not included. We recommend screening patients for OSA whenever the airway dimensions seem to be reduced. This helps the clinicians in proper treatment planning while managing OSA patients with combined cervical spine pathology.

V. Conclusion

In conclusion, our study showed a significant association between the minimum constricted area in the upper airway and the presence of cervical spine lesions. Also, the frequency of cervical spine degenerative changes is higher in the aged population over 50 years, irrespective of gender. Further studies have to be done in a wider range of age groups and with a more diverse population, which could considerably increase our understanding and help refine clinical diagnosis and treatment planning in these cases.

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