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Evaluation of the Role of Cone-Beam Computed Tomography as an Adjunctive Radiographic Modality to Enhance the Surgical Outcomes in Obstructive Sleep Apnoea Patients

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ABSTRACT

Purpose: *To evaluate the integration of Cone-beam Computed Tomography (CBCT) as an auxiliary radiographic modality for airway assessment to pinpoint blockage locations and improve Obstructive Sleep Apnea (OSA) surgical results.*

Material and methods: *Thirty-eight OSA patients were selected from the ENT outpatient clinic, Faculty of Medicine, Mansoura University, and divided into two equal groups. After performing polysomnography and recording the Apnea Hypoapnea Index (AHI), Drug-Induced Sleep Endoscopy (DISE) was carried out for both groups. CBCT imaging was performed for group (1) patients only. Afterward, the otolaryngologist selected the suitable surgical procedure for all patients. Post-surgical results were assessed six months after surgery. Another polysomnography was used to compare the postoperative AHI value to the preoperative value. At least a 50% reduction in the postoperative value was considered a conventional surgical success.*

Results: *A significant difference in AHI values before and after the operation between both groups was shown. Group (1) reduced by 55.7% more than group (2), which reduced by 30.7%. There was no statistically significant difference between the success rates of the two groups.*

Conclusion: *CBCT quantifies airway obstruction preoperatively, serving DISE, and thus improving OSA surgical success. Better collapse extent assessment using CBCT improves results and prospects. Future studies should explore specialists' CBCT use with larger sample sizes and a wider spectrum of OSA patients with different AHI levels.*

Keywords: *Obstructive Sleep Apnea; Cone-Beam Computed Tomography; Drug-Induced Sleep Endoscopy; Polysomnography; Airway Obstruction.*

Introduction

Obstructive sleep apnea (OSA) is a prevalent condition that has been associated with several severe negative outcomes such as heightened risk of accidents, cardiovascular issues, and elevated death rates [1,2] The severity of OSA is determined by the Apnea Hypopnea Index (AHI) and oxyhemoglobin saturation (SpO_2), two of the polysomnographic (PSG) parameters. OSA is classified as mild (AHI = 5-15 events/hour and SpO_2 = 86-91%), moderate (AHI = 15-30 events/hour and SpO_2

= 76-85%), or severe (AHI 30 events/hour and SpO_2 75%) [3].

Anatomical narrowing of the Upper Airway (UA), insufficient activation of the UA dilator muscles, low arousal threshold, and unstable ventilatory regulation are just some of the pathophysiological factors that lead to airway collapse.[4] Additionally, craniofacial pattern and bone phenotype characterization may be considerable parameters for diagnostic guidance and multidisciplinary planning of OSA treatment [5,6].

Successful treatment of OSA requires focusing on the assessment of the vulnerable collapsible anatomical spots. The collapse of the UA is frequently observed to be multilevel and may manifest at four distinct sites: the soft palate, tongue, lateral pharyngeal walls, and the larynx.[7, 8] OSA patients are diagnosed by multi-step procedures involving many sleep scales and tests as the prediction of UA problems cannot be made with a high degree of sensitivity and specificity using a single airway space examination.[9]

Three-Dimensional (3D) radiographic assessment; Computed Tomography (CT), and Cone-Beam Computed Tomography (CBCT) can evaluate the airway's bony encasing structures.[10] CBCT is widely regarded as the most fitting option for 3D dental sleep imaging because of its exceptional spatial resolution, which facilitates the discrimination of various structures, including bone, hollow spaces, and soft tissues with low radiation doses.[11] In addition, the utilization of specialized analysis software that incorporates sophisticated thresholding techniques, coupled with the advancement of computer-aided diagnostic procedures, can successfully tackle the validation of anomalies that lack soft tissue contrast [12].

On the other hand, identifying the degree of obstruction and the anatomical structure of the airway's soft tissue and lumen while the patient is asleep is crucial. Drug-induced sleep endoscopy (DISE) may reveal an anatomical blockage that provides valuable insights into the extent, severity, and orientation of UA collapse [13]. However, this procedure requires an anesthesiologist, operating room, and safety tracking systems, making it time-consuming and expensive.[8] The direct vision of varying levels of collapse, as described by Croft and Pringle in 1991, may help in the choice of the appropriate surgical intervention.[14] It has been shown that DISE helps guide the therapy decision process for people with OSA, however, there is little evidence that it improves the treatment results as the lack of DISE uniformity makes it hard to compare studies conducted at different sleep clinics.[15] Although the first line of OSA treatment is non-surgical, mainly Continuous Positive Airway Pressure (CPAP), many patients, however, cannot tolerate this device and request surgical procedures as an alternative treatment option.[16] Upper Airway Surgery (UAS) may be considered an effective therapeutic approach, particularly in individuals with moderate OSA who have significantly obstructed airways that are surgically correctable, and in patients with CPAP failure.[17, 18] The most effective UAS in adults is the maxillomandibular advancement (MMA) and Uvulo-palate-pharyngoplasty (UPPP) surgeries.[19] It is worth noting that the primary factor contributing to the failure rate of UPPP surgery, which can be as high as 60%, is attributed to inadequate identification of the precise location of UA obstruction.[20, 21] Due to the monitoring equipment limitations in determining the location of obstructions in the UA, therapeutic strategies targeting specific levels, including UAS have demonstrated very modest rates of efficacy.[22]

In this respect, this study aims to evaluate the role of CBCT as an adjunctive radiographic modality for airway assessment to localize the obstruction sites, therefore improving the outcomes of OSA surgical treatment.

Materials and Methods

The present study comprised a cohort of 38 patients diagnosed with OSA, who were elected with great care from the outpatient sleep treatment clinic at Mansoura University Hospital. Sample size calculation was based on the difference in AHI between DISE and non-DISE groups retrieved from Pang et. al.'s previous research.[8] Using G power program version 3.1.9.7 to calculate sample size based on the effect size of 0.95, using the 2-tailed test, α error=0.05 and power= 80.0%, the total calculated sample size was 19 patients in each group. On January 26, 2021, the study was registered at www.clinicaltrials.gov and recorded as OCS05051989.

After a comprehensive history and clinical examination, only patients who disregarded CPAP and had a clear indication for UAS were included. All selected patients had a PSG performed before surgery, and the preoperative AHI was collected for everyone. Following a thorough explanation of the study procedures, written informed consent was acquired from all participants. The participants were randomly allocated into two groups. Group (1) included 19 patients who had UAS after determining the degree of collapse based on data obtained from both DISE and CBCT scanning. A total of 19 patients in group (2) underwent UAS after examination with DISE alone. All procedures conducted in this study were approved by the ethical committee on human research at Cairo University, both at the institutional and national levels. The research was conducted in compliance with the Helsinki Declaration of 1964 and its revisions.

For both groups, the upper airway collapse was assessed using DISE preoperatively by an ENT surgeon. During DISE, the patients were supine on the operation table where they had pulse oximetry, blood pressure, ECG, and oxygen masks. Sleep was induced with 1.5 mg/kg propofol and the target sedation depth was when the patient choked, snored, and lost vocal response. Slow stepwise induction with propofol, an ultra-short-acting hypnotic, prevented oversedation during sleep endoscopy. After appropriate sedation, a 3.5 mm lubricated flexible endoscope was inserted nasally. The nasal channel, nasopharynx, velum, tongue base, epiglottis, and larynx were inspected as shown in Figure 1.

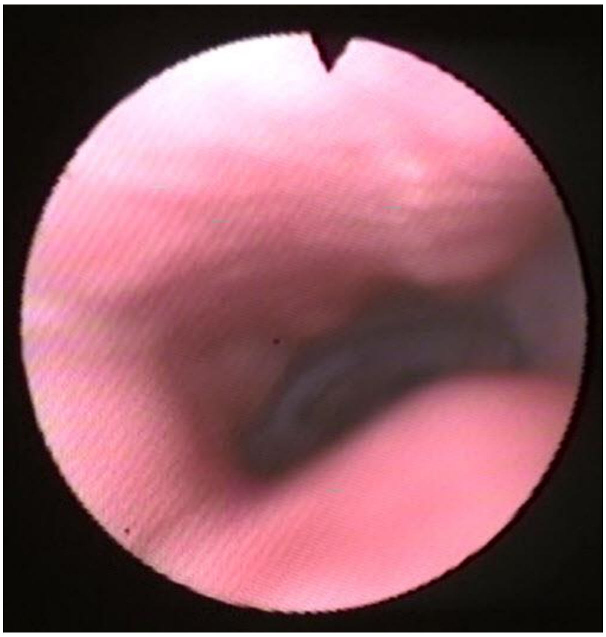

Figure 1: A single perspective of Drug-Induced Sleep Endoscopy (DISE) examining pharyngeal airway

Patients in Group (1) had an extra radiographic assessment utilizing the iCAT FLX V17-Series CBCT equipment, manufactured by Imaging Science International (ISI) in Pennsylvania, USA. The imaging process included a quick scan with a field of view (FOV) measuring 16cm × 13cm and 0.3mm voxel size with imaging parameters as follows; 120 KV, 5 mA, and 2 seconds exposure time. The participants were required to put on a lead apron during the scanning procedures. Following a comprehensive evaluation of the clinical examination, DISE, and CBCT radiographic assessment of each patient in group (1) as shown in Figure (2) and DISE only for patients of the group (2), the otolaryngologist made a well-informed decision regarding the appropriate surgical intervention. The evaluation of post-surgical outcomes was conducted six months following the date of the procedures. The evaluation was conducted by comparing the postoperative AHI value with the preoperative value, using another sleep study as a basis for assessment. Conventional surgical success rate has been characterized as achieving an AHI reduction of at least 50% in the postoperative value.[23]

Data was analyzed using SPSS (Statistical Package for Social Sciences) version 22. Qualitative data was presented as numbers and percentages, Quantitative data was tested for normality by the Shapiro-Wilk test and then described as mean and standard deviation for normally distributed data and median and range for non-normally distributed. The appropriate statistical tests were applied according to the data type with the following suggested tests: Student t-test, Mann Whitney U test, Chi-Square for categorical variables, and Spearman or Pearson correlation were used to correlate continuous variables.

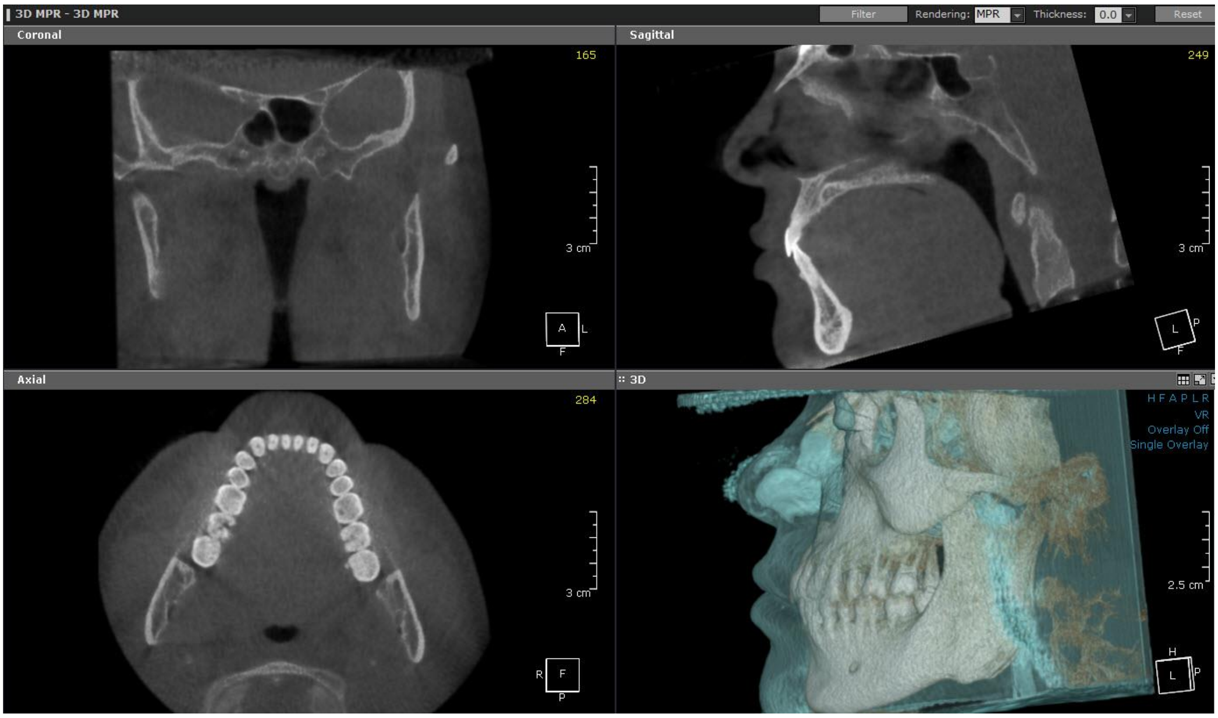

Figure 2: CBCT orthogonal planes and 3D model with airway preset displayed by On Demand 3D App (Cybermed Inc., Seoul, Korea) showing retropalatal obstruction in the sagittal and coronal plane.

Results

Both groups underwent post-surgical success evaluation after 6 months by comparing pre-operative and post-operative AHI values, disease severity, and success rate. The comparison of pre-operative and post-operative AHI values using the Mann-Whitney U test revealed no statistically significant difference between group (1) and group (2) in the pre-operative AHI value. On the other hand, there was a statistically significant difference in the post-operative AHI value (p-value<0.05), as indicated in Table (1). However, both groups had a statistically significant disparity in the AHI values before and after the operation, as determined by the Wilcoxon signed rank test. Group (1) had a higher percentage of reduction compared to group (2), with values of 55.7% and 30.7% respectively as presented in Figure 3.

Table 1: Comparison between the pre-operative and post-operative AHI values among the studied groups.

	Group (1) **DISE + CBCT**	**Group (2)** **DISE only**	**Test of significance** **(Mann Whitney U test)**
Pre-operative AHI value	53.42±25.07 48(7-113)	55.42±25.98 49(23-120)	Z=0.175 P=0.861
Post-operative AHI value	23.68±15.45 20(4-60)	38.42±18.11 35(16-76)	Z=2.66 P=0.008*
Wilcoxon signed the rank test	Z=3.82 P<0.001*	Z=3.83 P<0.001*	-

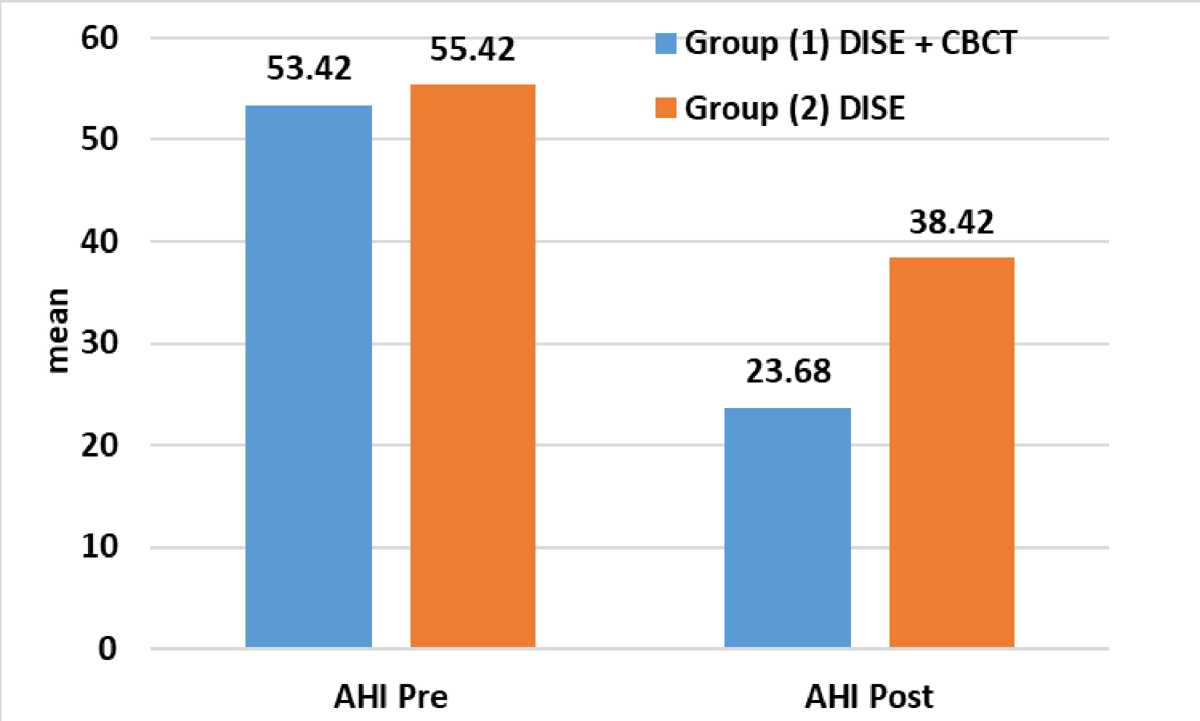

Figure 3: Comparison between the reduction values in the pre-operative and post-operative AHI among the studied groups.

As indicated in Table (2), the disease severity based on the pre-operative AHI value was categorized as moderate and severe, and there was no significant difference between the two groups. The application of the Monte Carlo test revealed a statistically significant difference in post-operative severity classification between the two groups. Group (1) showed that over 70% of the cases have transitioned to mild and moderate cases, but Group (2) exhibited no mild cases and 26% moderate instances. In contrast, group (2) had a severity rate of over 70% for most of the cases, with only 26% transitioning to a moderate level. Nevertheless, a significant statistical disparity was observed between the two groups in terms of the severity before and after the operation.

Table 2: Comparison between disease severity in pre-operative, and post-operative among the studied groups.

Severity		Group (1) DISE + CBCT	Group (2) DISE only	Test of significance (Monte Carlo test)
Pre-operative	Moderate	3(15.8)	3(15.8)	P=1.0
	severe	16(84.2)	16(84.2)	
Post-operative	Mild	7(36.8%)	0	Mc =11.59 P=0.003*
	Moderate	7(36.8%)	5(26.3%)	
	Severe	5(26.3%)	14(73.7 %)	
Wilcoxon signed the rank test		Z=3.82 P<0.001*	Z=3.83 P<0.001*	-

*Parameters described as number (percentage), MC: Monte Carlo test, *statistically significant.*

The success rate was defined by an AHI reduction of at least 50% in the postoperative value.[22] Considering the data in Table (3), both groups achieved a high success rate, with 100% of patients in group (1) and 89.5% of patients in group (2) experiencing success. There was no statistically significant difference between the success rates of the two groups.

Table 3: Comparison between the success rates among the studied groups.

	Group (1) DISE + CBCT N (%)	Group (2) DISE N (%)	Test of significance (Fisher exact test)
Success rate	19(100.0)	17(89.5)	P=0.146

Discussion

This research endeavor aimed to evaluate the disparity in outcomes following surgery between two distinct cohorts. The primary differentiation between the groups was the way group (1) utilized CBCT findings in conjunction with DISE as an additional approach to improve surgical outcomes unlike group (2) where surgery was undergone based on DISE results only.

DISE is a dependable and efficient approach to evaluating the incidence of dynamic collapse in the UA during sleep. It is advantageous in determining treatment options for individuals with OSA. While DISE is frequently employed to aid in surgical decision-making, there is a lack of data establishing a correlation between DISE and enhanced surgical outcomes.[15] Thus, a pivotal inquiry that necessitates a response is whether the utilization of DISE alone or CBCT with DISE alters surgical planning, therefore improving the rates of surgical success.

CBCT is the optimal modality for 3D dental sleep imaging owing to its exceptional spatial resolution.[11] Although DISE determines collapse level dynamically, CBCT is an effective supplementary imaging tool for upper airway dysfunction evaluation. For OSA patients with tongue-palate contact or an expanded palate, orthogonal plane CBCT planes yield unmistakable results.[24] CBCT cannot determine collapse severity alone. Instead, use it as a powerful imaging tool to quantify upper airway dysfunction.

Our results in group (2), where candidates undergone DISE only before surgery showed a statistically significant difference between the pre-operative and post-operative AHI values. The results of this study were consistent with the findings of Colin Huntley et.al.[25], who reported a success rate of 86% in patients who underwent preoperative DISE, compared to 51.4% in those who did not undergo preoperative DISE ($p < 0.001$). Moreover, the initial surgical plan has been altered due to the introduction of DISE, as many authors have shown. On 38 OSA patients, Gillespie et al.[26] discovered that 62% of the plans had changed because of DISE. In a similar vein, Eichler et al.[27] showed that 63.9% of the time, surgical plans were altered by DISE in 97 OSA patients.

Likewise, group (2), and group (1) also demonstrated a statistically significant distinction in pre- and post-operative AHI values, suggesting that surgical outcomes are almost indistinguishable based on both CBCT and DISE. The importance of CBCT in identifying the level of collapse can be explained by considering it as an advanced 3D imaging technique that provides precise information on the level of collapse, which can then be confirmed by DISE. The findings of our investigation were consistent with a study conducted by Aboelmaaty et.al.,[24] which revealed that there was no significant difference in the level of collapse identified using DISE or CBCT in the majority of instances.

The random allocation of the patients in our study demonstrated an equal distribution of moderate and severe cases, with 3 and 16 cases respectively. While there was no statistically significant difference in the AHI categories between the post-operative and pre-operative stages in both groups, group (1) had a total of 7 cases classified as mild, 7 cases classified as moderate, and 5 cases classified as severe. In contrast to group (2), which led to 5 cases of moderate severity and 13 cases of severe severity. These clinically significant findings demonstrate the need to use CBCT in combination with DISE for advanced post-operative success.

A related study was performed on 30 OSA patients who were separated into two groups and underwent DISE to evaluate the extent of airway collapse. A cohort of patients underwent CBCT imaging. An extremely notable disparity of 64.7% decrease was observed between the average and middle values of pre-and postoperative AHI.[24] Similarly, our study found that group (1) patients had a 100% success rate, whereas group (2) patients had an 89.5% success rate. This indicates that CBCT has an important therapeutic value in enhancing the success rate, namely in achieving an AHI reduction rate of above 50%.

Conclusion

CBCT is an advanced 3D dental-sleep imaging technology with a reduced level of radiation. CBCT complements DISE in the preoperative airway assessment by defining the obstruction levels, hence improving the outcomes of OSA surgical treatment.

Recommendation

CBCT views should be regarded as a superior technique for determining the extent of collapse, yielding improved results with a significant impact on prospects. Anticipated future studies should assess the trends in the use of CBCT by specialists with larger sample sizes over a wider spectrum of OSA patients with different AHI levels.

Additional Information

Consent was obtained or waived by all participants in this study.

Conflicts of Interest

None.

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