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Original Paper

Diagnostic Accuracy of Cone-Beam Computed Tomography in the Evaluation of Chronic Rhinosinusitis

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Key Words
Agreement · Accuracy · Chronic rhinosinusitis · Cone-beam computed tomography

Abstract
Introduction: This study assessed the agreement of cone-beam computed tomography (CBCT) scan and sinus endoscopy findings and attempted to find a diagnostic accuracy of CBCT in patients with chronic rhinosinusitis (CRS). ***Methods:*** Forty-two patients with CRS referred to the Aria and 22 Bahman Hospitals in Mashhad, Iran, during the year 2011 were included in this cross-sectional study. Paranasal sinus CBCT scanning and endoscopy were performed in all patients. The sensitivity, specificity, positive and negative predictive values (PPV and NPV), and accuracy of CBCT were determined, and the agreement between CBCT and endoscopy findings was evaluated. ***Results:*** In most of our findings, except for infundibulum thickening, there was a strong agreement between CBCT and paranasal sinus endoscopy, with a kappa coefficient >0.80 ($p < 0.05$). The sensitivity, specificity, PPV, NPV, and accuracy of CBCT were >80% for most of the findings, except for infundibulum thickening and septal deviation. ***Conclusion:*** CBCT has nearly the same diagnostic accuracy as sinus endoscopy. The accuracy of CBCT scanning is high, and CBCT findings are well correlated with sinus endoscopy findings. Considering its high accuracy and lower costs and radiation doses, CBCT may be a proper alternative method for diagnostic sinus endoscopy in the assessment of CRS in patients with a contraindication for sinus endoscopy.
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Introduction

Chronic rhinosinusitis (CRS) is one of the most common chronic health conditions, and its incidence is increasing worldwide. CRS affects about 1 in 7 adults in the US population (prevalence rate of 12.5%) [1, 2]. CRS significantly reduces the patients' quality of life and causes functional and emotional impairment [3]. Various conditions contribute to the pathophysiology of CRS. The etiology of CRS may be inflammatory, such as viral, bacterial, and fungal infections, allergy and asthma, and polyposis, or noninflammatory, such as neural dysfunction, nociceptive dysfunction, and gastroesophageal reflux [4].

Due to its high sensitivity and specificity, standard computed tomography (CT) scanning is the gold standard method for CRS diagnosis [5, 6]. Despite the high accuracy of conventional CT scanning, its high costs and high radiation doses have limited its application [5, 6]. Considering the above-mentioned limitations of CT scanning, attempts have been made to find an alternative imaging modality without these limitations. One of these relatively new modalities is cone-beam CT scanning (CBCT). CBCT is a 3-dimensional (3D) X-ray-based volume acquisition imaging modality first introduced in 1998 [7]. It provides 3D images at lower costs and radiation dosages than conventional CT scanning [8]. The main advantages of CBCT over conventional CT scanning are lower radiation dose (10 times lower), lower costs, fewer artifacts, shorter scanning time, providing very thin slices in the axial, coronal, and sagittal planes, automatic generation of surface and volume reconstructions, easy access, and higher spatial resolution [9, 10]. Despite these advantages, CBCT has some limitations compared to conventional CT scanning, including poor density resolution in soft-tissue imaging, absence of a Hounsfield scale, and higher noise [11, 12].

Since its development, CBCT has been widely applied in dentistry for various purposes [9]. After these primary applications, CBCT has gained popularity and is now increasingly being used for the diagnostic imaging of the head and neck region and the ear, nose, and throat area [13–15]. CBCT is a useful modality for detecting mucosal thickness, nasal septum deviation, conchal hypertrophy, bullous concha, and retention cysts in these areas [16]. In spite of these advances in the application of CBCT in the head and neck area, the diagnostic accuracy of this technique for these regions has rarely been studied [10].

Endoscopy of the paranasal sinuses allows the observation of anatomical areas and the evaluation of sinonasal lesions and their relationship with endonasal structures. Diagnostic sinus endoscopy is an invasive and costly method for the assessment of CRS that needs local or general anesthesia. In addition, it cannot be applied to all patients, may be difficult or impossible in children, and may be associated with severe complications [17]. Regarding these limitations, finding an alternative diagnostic modality is beneficial. CBCT may be an alternative modality for diagnostic sinus endoscopy. The main objectives of this study were to investigate the agreement between CBCT scanning and sinus endoscopy in the detection of pathologic changes and to find a diagnostic accuracy of CBCT in patients with CRS.

Materials and Methods

This cross-sectional study was performed at the Aria and 22 Bahman Hospitals in Mashhad, Iran, during the year 2011, and 42 patients with CRS were evaluated. The study protocol was in accordance with the ethical principles of the Helsinki Declaration (1964) and was approved by the Ethics Committee at the medical branch of Izlamic Azad University, Mashhad, Iran. All patients gave written informed consent before enrollment.

Patients with a confirmed diagnosis of CRS based on the American Society of Head and Neck Surgery (AHNS) criteria [18] and an indication for the evaluation of CRS by imaging were included in the study. Eligible patients were selected among those with CRS referred to the Aria and 22 Bahman Hospitals and to a

Table 1. Agreement between CBCT and paranasal sinus endoscopic findings in CRS patients

Finding	CBCT	Endoscopy	No endoscopy	Kappa coefficient	p value
Polyp	Yes	11 (76.8)	0 (0)	0.81	0.0001
	No	3 (21.4)	28 (100)		
Infundibulum thickening	Yes	15 (100)	9 (33.3)	0.59	0.0001
	No	0 (0)	18 (66.7)		
Bilateral osteomeatal complex	Yes	13 (100)	3 (10.3)	0.84	0.0001
	No	0 (0)	26 (89.7)		
Septal deviation	Yes	34 (100)	2 (25)	0.83	0.0001
	No	0 (0)	6 (75)		
Middle turbinate hypertrophy	Yes	18 (90)	1 (4.5)	0.86	0.0001
	No	2 (10)	21 (95.5)		
Sinus opacity	Yes	13 (86.7)	0 (0)	0.89	0.0001
	No	2 (13.3)	27 (100)		

Values are numbers with percentages in parentheses.

private office in Mashhad, Iran, by the convenience sampling method. Patients without AHNS criteria for CRS, those with previous functional endoscopic sinus surgery (FESS), advanced age, heart disease, and chronic disorders, and those with contraindications for CBCT or FESS were excluded from the study.

Finally, 42 patients were included and underwent CBCT scanning. Coronal and axial planes of all paranasal sinuses were obtained using the ProMax® 3D Max CBCT unit (Planmeca Oy, Helsinki, Finland). CBCT was performed with a spatial resolution of 400 μm (voxel size 0.4 mm), an image size of 250 × 250 × 250 pixels, a voltage of 90 kV, a current of 9 mA, an exposure time of 12 s, and a radiation dose (dose area product) of 1,578 mGy × cm^2.

After obtaining CBCT images, patients with positive pathologic findings on CBCT underwent therapeutic sinus endoscopy under general anesthesia, and those without pathologic findings on CBCT underwent diagnostic sinus endoscopy under regional anesthesia within 1 week after CBCT scanning. Then, the rates of pathologic findings on CBCT and endoscopy were compared, and the agreement between the two diagnostic modalities was evaluated. FESS was considered as the gold standard method for the diagnosis of CRS. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of CBCT were calculated by comparison with FESS. For the assessment of agreement, findings including polyp, infundibulum thickening, bilateral osteomeatal complex, septal deviation, middle turbinate hypertrophy, sinus opacity, foreign body, and unilateral choanal atresia were compared between the two modalities. A single radiologist who was blinded to the findings of FESS evaluated the CBCT images.

Statistical Analysis

Data are presented as mean and standard deviation (SD) for numerical data and number and percentage for categorical data. Data analysis was performed using SPSS software version 20.00 for Windows and Statistica version 10.00. To evaluate the agreement between the two modalities, kappa statistic was used. The significance level was set at a p value <0.05.

Results

In this study, 42 patients with CRS were assessed. The mean age of the participants was 37± 14.4 years, and 31% of them were female (13 patients). There was a near perfect significant agreement between CBCT and FESS in the findings of the pathologic lesions (table 1).

Table 2. Sensitivity, specificity, PPV, NPV, and accuracy of CBCT in comparison with sinus endoscopy

Finding	Sensitivity	Specificity	PPV	NPV	Accuracy
Polyp	78.6	100	100	90.3	92.8
Infundibulum thickening	100	66.7	62.5	100	78.6
Bilateral osteomeatal complex	100	89.7	81.3	100	92.8
Septal deviation	100	75	94.4	100	95.2
Middle turbinate hypertrophy	90	95.5	94.7	91.3	92.8
Sinus opacity	86.7	100	100	93.1	95.2

Values are percentages.

The agreement between the two methods was statistically significant ($p < 0.05$). In most of the studied pathologies, including the diagnosis of polyp, bilateral osteomeatal complex, septal deviation, middle turbinate hypertrophy, and sinus opacity, there was a strong significant agreement between CBCT and FESS with a kappa coefficient of >0.80 ($p < 0.001$ for all; table 1). The prevalence of the mentioned pathologic findings by CBCT and FESS was comparable. However, there was a moderate agreement between these two methods for the finding of infundibulum thickening (kappa coefficient 0.59; table 1). Foreign body and unilateral choanal atresia were not detected in our patients by the two methods. The sensitivity, specificity, PPV, NPV, and accuracy of CBCT are shown in table 2.

Discussion

This study found a strong significant agreement between CBCT and FESS in the detection of pathologic findings in CRS patients. Also, the sensitivity, specificity, and accuracy of CBCT were acceptable compared to FESS.

CBCT has been widely used in dental practice for various purposes such as maxillary sinus evaluation, oral surgery, evaluation of temporomandibular joint, orthodontic evaluation, implant planning, and craniofacial trauma evaluation and treatment [9, 19]. Most of the studies in dentistry have evaluated the usefulness of CBCT in the visualization of the maxillary sinus and in identifying the odontogenic origin of maxillary sinusitis and confirmed that CBCT can elucidate a potential dental etiology of maxillary sinusitis [20–24]. The main limitations of CBCT in dental practice are its higher costs and higher radiation doses compared to conventional radiography [20]. However, studies have shown that CBCT is an effective imaging modality for the assessment of odontogenic and non-odontogenic sinusitis and sinusitis of unknown etiology [25].

In addition to its application in dentistry, CBCT has increasingly been used in the ear, nose, throat, head, and neck area. The accuracy of CBCT has been approved for the assessment of the anterior skull base, olfactory tract, upper airway, and paranasal sinuses [26–28]. The overall rate of pathologic findings in maxillary sinus detected by CBCT scanning was reported to be 56.3% by Ritter et al. [29], with mucosal thickening being the most frequent pathology (38.1%), followed by partial calcification, opacification, and polypoidal mucosal thickening. They concluded that CBCT was an appropriate technique for the diagnosis and treatment planning of sinusitis [29].

The most common incidental findings in the maxillofacial region detected by CBCT have been reported to be in the airway area, followed by impacted teeth, temporomandibular joint, and endodontic findings, which have been reported with different rates in different studies

[16, 30]. Previous studies concluded that CBCT is efficient in detecting incidental findings [16, 30]. A study in Iran that investigated the accuracy of CBCT compared to conventional CT scanning in the evaluation of paranasal sinuses found no significant difference in the efficacy of the two modalities, and the findings were completely consistent [31]. Considering the lower radiation doses, they suggested the application of CBCT before surgery instead of conventional CT scanning [31]. Khorrami Nejad et al. [32] found a good correlation between the findings of conventional CT scanning and endoscopy in the diagnosis of sinusitis. They found that endoscopy was not a proper diagnostic method for the diagnosis of concha and septum anomalies [32]. Shahbazian and Jacobs [33] reviewed the accuracy of 2D and 3D imaging in the diagnosis of odontogenic maxillary sinusitis and found that CBCT was superior to 2D imaging in the diagnosis of maxillary sinusitis because conventional CT may obscure the odotogenic origin of maxillary sinusitis. In Korea, Woo et al. [10] evaluated the efficacy of CBCT for the preoperative evaluation of endoscopic sinus surgery in 50 patients. They compared the CBCT findings using the half Lund-Mackay score with the endoscopic findings of sinusitis and observed a significant correlation between them. In their study, the Lund-Mackay and sinusitis severity scores were 5.26 and 5.02, respectively, and the surgeons' satisfaction level was high [10]. They concluded that CBCT was a useful imaging modality for the preoperative assessment of paranasal sinuses [10]. Their study methods and findings were similar to ours, as we compared the CBCT findings with those of paranasal sinus endoscopy as a valuable objective method for the evaluation of sinus pathology. However, we calculated the sensitivity, specificity, PPV, NPV, and accuracy of CBCT and evaluated the agreement of its findings with sinus endoscopy, which has not been performed in the study by Woo et al. [10]. The difference between their and our study is that we did not calculate the Lund-Mackay score. Except for the latest one, we found no study comparing the accuracy of CBCT with paranasal sinus endoscopy in the diagnosis of CRS, and our study findings are beneficial in this regard.

The small sample size, the lack of comparison of CBCT findings with those of conventional CT scanning, and no application of the Lund-Mackay score are the main limitations of our study. However, future studies with a greater sample size comparing the accuracy and agreement of CBCT with conventional CT scanning and paranasal sinus endoscopy are required to confirm the present study findings.

In conclusion, our study revealed a high sensitivity, specificity, and accuracy of CBCT scanning and found a strong agreement between CBCT and sinus endoscopy in the detection of pathologic changes. Considering the reduced invasiveness and the lower costs of CBCT, it may be applied as an alternative method for diagnostic sinus endoscopy in the assessment of CRS in patients with a contraindication for sinus endoscopy or in children. Also, due to the high accuracy and lower costs and radiation doses of CBCT, it may be used as an alternative method for conventional CT scanning in the assessment of CRS.

Disclosure Statement

The authors have no conflict of interest to declare.

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