Original Article

Role of computed tomography in identifying anatomical variations in chronic sinusitis: An observational study

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Abstract

Background/Aim: Clear visualization of bony wall, mucosal layer, sinus contents, and compartment by computed tomography (CT) helps to identify the anatomical variations in chronic sinusitis (CS). We describe the clinical and radiological features in CS.

Materials and Methods: We included patients of both genders aged ≥15 years, with CS. Unenhanced CT images of the nasal cavity and paranasal region were taken in coronal, complemented by axial and sagittal reconstructions. Analysis of anatomical variants was performed using a soft tissue window and a bone window.

Results: Headache (64%), nasal obstruction (53%), and nasal discharge (38%) were common complaints of 100 patients (male = 52) whose mean ± standard deviation age was 32.55 ± 10.9 years. Significant mucosal thickening in at least one of the paranasal sinuses (PNSs) was seen in all except four patients. All had a minimum of one anatomical variant, 72% had >1 variant. Maxillary antra were most commonly involved (62.0%), followed by ethmoid sinuses (36.0%). Deviated nasal septum (60%) was most common, followed by concha bullosa (38%); paradoxical middle turbinate (18%), ethmoidal bulla (20%), agger nasi cells (33%), Haller cells (21%), and onodi cells (10%) were other features. All had optic nerve involvement with Type I (84%) involvement being common. Kero's classification Type I was noted in 71%. None had Type IV. Cribriform plate and carotid canal wall were normal in all while 2% had dehiscence of lamina papyracea.

Conclusion: CT plays an important role in visualization of anatomical variations in PNSs, and anatomical variations particularly in the ostiomeatal complex are the key factors in the causation of CS.

Keywords: Anatomical variations, chronic sinusitis, computed tomography, deviated nasal septum, Kero's classification

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INTRODUCTION

Anatomical variations in the paranasal region blocking the ostiomeatal complex lead to the development of chronic sinusitis (CS) and influence the treatment outcome.[1,2] Detection of these variation prevents the potential surgical hazards,[3] and detection is more accurate with radiology. Conventional radiography does not permit a detailed study of this region, hence, now largely replaced by computerized tomographic (CT) imaging.

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With the advent of functional endoscopic sinus surgery (FESS) and coronal CT imaging, considerable attention has been directed toward paranasal region. CT scanning with thin coronal slices has proven useful because the orientation of anatomy is similar to that encountered in FESS.

MATERIALS AND METHODS

This study was conducted by the Department of Radiodiagnosis of a medical college after obtaining the Institutional Ethics Committee's approval. We conducted this study to evaluate the diagnostic role of CT of paranasal sinus (PNS) in CS as the data on Indian population are limited. As anatomical variations defer from region to region, race to race, we compared with other studies to see if there is any significant change in the occurrence of anatomical variations.

Prospective patients were identified from those who were clinically diagnosed with CS, advised CT scan of PNS, and were screened after obtaining the written consent. We included patients of both genders aged ≥15 years, with a history of CS and excluded those with previous history of trauma, previous nasal/PNS surgeries, and those with nasal/PNS tumors.

Unenhanced CT images of the PNS and paranasal region were taken in coronal, complemented by axial and sagittal reconstructions. Analysis of anatomical variants was performed using a soft tissue window and a bone window.

In all cases, the existence of the following variants was investigated: (1) nasal septum: septal deviation; (2) turbinates: concha bullosa, paradoxical middle turbinate; (3) uncinate process (UP): pneumatization, medialized, lateralized; (4) ethmoid air cells: agger nasi cells, Haller cells, ethmoid bulla, onodi cells.

Associated anatomy of the paranasal regions such as the course of optic nerve, dehiscence of cribriform plate, and asymmetry of the ethmoidal roof was also investigated. Involvement of optic nerve was classified into four types (Type I–IV).[4] The depth of olfactory fossa was classified according to Kero's classification,[5] into three types.

The investigations were performed using Siemens Somatom Emotion 16 slice spiral CT machine (multidetector CT). Direct scans of 0.6 mm thickness were made from the anterior walls of the frontal sinuses to the posterior wall of the sphenoid sinus. The exposure settings used were 130 kVp and 80 to 100 mAs.

RESULTS

One hundred patients (male = 52, female = 48) meeting the selection criteria were included, of which 55% were in the 15–30 years age group [Figure 1]. The mean ± standard deviation (SD) age was 32.55 ± 10.9 years. The youngest patient was 15 years, and the oldest was 60 years.

Headache (*n* = 64, 64%), nasal obstruction (*n* = 53, 53%), and nasal discharge (*n* = 38, 38%) were the most common complaints. Significant mucosal thickening in at least one of the PNSs was seen in all except for four patients in whom it was negligible. At least one anatomical variant was noted in every patient in the study group while more than one variant was seen in 72% [Table 1].

Radiological evidence of sinusitis was noted in 96% of patients, and at least one of the PNSs was noted in all. Maxillary antra were the most commonly involved (62.0%), followed by ethmoid sinuses (36.0%), sphenoid sinuses (38.0%), and the frontal sinuses (36.0%) [Table 2]. Pansinusitis was seen in 7% of them; confirmed involvement of more than one sinus was seen in 59% [Table 3].

Anatomic variations

Deviated nasal septum (DNS) was the most common variation (60%), followed by concha bullosa (38%), paradoxical middle turbinate (18%), ethmoidal bulla (20%), agger nasi cells (33%), Haller's cells (HC) (21%), onodi cells (10%) [Figure 2].

DNS was categorized into right-sided DNS (*n* = 27, 45%), left-sided DNS (*n* = 25, 41.67%), and "S"-shaped DNS (*n* = 8, 13.33%). UP variations were lateralized, medialized, and pneumatized UP. The most common being medialized UP (*n* = 18, 75%), lateralized UP (*n* = 4, 16.67%), and pneumatized UP (*n* = 2, 8.33%).

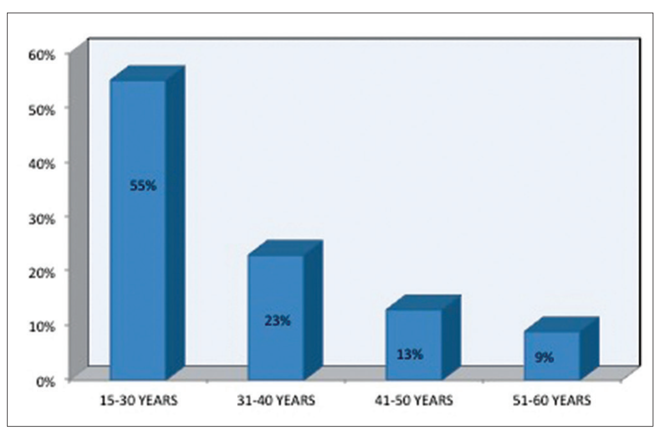

Figure 1: Age distribution among the study population

Optic nerve was classified into four types based on their course and association with the adjacent sphenoid sinus. Optic nerve involvement was seen in all (100%) patients with Type I involvement being more frequent [Table 4].

The depth of olfactory fossa was classified according to Kero's classification, which consists of three types. Type I was noted in 71%, Type II in 26%, and Type III in 3% patients. Asymmetry was noted in 14% of the patients. None of our patients belonged to Type IV [Table 5].

We evaluated the dehiscence of cribriform plate, lamina papyracea, and carotid canal wall to assess the extent and severity of the disease. Only in 2% of patients was dehiscence of lamina papyracea noted whereas no abnormality was detected in cribriform plate and carotid canal wall.

Table 1: Anatomical variations in the study population

Number of anatomical variation	Frequency (%)
One	18 (18.0)
Two	46 (46.0)
Three	30 (30.0)
Four	6 (6.0)
Total	100 (100.0)

Table 2: Involvement of paranasal sinuses

Sinuses	Incidence (*n*=100)			
	Right (*n*)	Left (*n*)	Bilateral (*n*)	Total *n* (%)
Frontal	12	08	16	36 (36%)
Maxillary	13	17	32	62 (62%)
Ethmoid	18	15	15	48 (48%)
Sphenoid	17	14	07	38 (38%)
Total	59	55	70	184

Table 3: Disease load per patient

Number of sinuses involved	Frequency (%)
0	6 (6.0)
1	35 (35.0)
2	35 (35.0)
3	17 (17.0)
4	7 (7.0)
Total	100 (100)

Table 4: Optic nerve involvement

Optic nerve involvement type	I	II	III	IV	Left side total
I	75	6	3	0	84
II	1	7	2	0	10
III	0	0	4	1	5
IV	0	1	0	0	1
Right side total	76	14	9	1	100

Table 5: Depth of olfactory fossa (Kero's classification)

Kero's classification type	I	II	III	Left side total
I	64	6	0	70
II	6	19	0	25
III	1	1	3	5
Right side total	71	26	3	100

DISCUSSION

Complicated anatomy of the PNSs and their frequent variations have been implicated in chronic rhinosinusitis. Exact assessment of these anatomic variations is important not only in the clinical evaluation and treatment but also in the endoscopic surgical management.[6-8] Doubts have been raised over the role of anatomical variations in the development of CS[9] although the available evidences signal the increased risk of developing CS with anatomical variations.[10-12]

CT scans changed the outlook of diagnostic investigations in otolaryngology as they aided the clinician in the precise diagnosis.[13] Conventional CTs though gold standard in the investigation of CS have the disadvantage of greater exposure to radiation and of being expensive. Improvement in the techniques in CT imaging have revolutionized the diagnostic approach in the patients with CS. Three slice CT was found to be useful with good sensitivity and specificity.[14] Understanding the anatomical variations and intrinsic mucosal pathology can result in better disease management and reduce surgical complications,[1,12,15,16] and CT scans are found to be efficient tool in distinguishing former and latter.[17]

CT of the PNSs has nowadays become the investigation of choice for the radiological diagnosis of nasal and sinus diseases. Unlike plain radiography, CT of this region shows an excellent anatomical details of soft tissue and bones, helps in accurate diagnosis, and gives detail of sinonasal anatomy for safe surgery.[18] Moreover, clear delineations in terms of better visualization of the bony wall, mucosal layer, and sinus compartment along with its contents provided by the CT images, make it a preferred and recommended diagnostic tool to identify the anatomical variations associated with CS.[19-22]

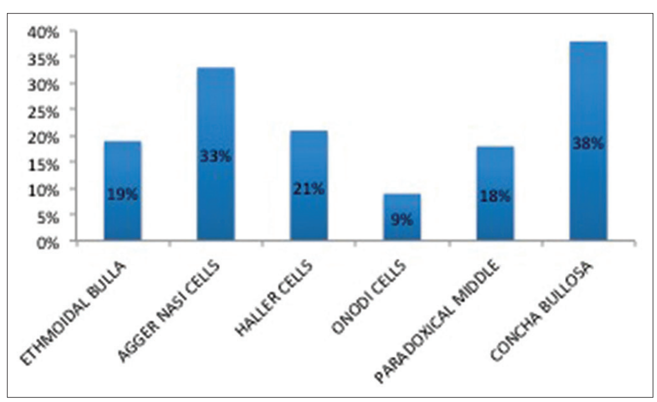

Figure 2: Anatomical variations

Mean ± SD age of our patients was 32.55 ± 10.9 years which was slightly less than that reported by previous reports (37 years).[23,24] We did not find any significant difference in age and gender as with previous reports.[23,24] Headache (64%) was the most frequent complaint of our patients (64%), followed by nasal obstruction (53%) and nasal discharge (38%), whereas Stammberger and Wolf reported nasal obstruction (82%), followed by nasal secretion (64%) and mild facial pain (62%).[25]

The association between anatomical variations and development of CS is well established.[26] Most CT anatomical studies of the sinus region have been made in patients suspected of a clinical syndrome suggesting inflammatory sinus pathology. Zinreich found that 62% of his patients presented at least one anatomic variant, against 11% in the normal control group.[27] These findings seem to suggest a positive correlation between anatomical variants and the appearance of inflammatory sinus pathology. Fadda *et al*. noted that 70% of the patients had anatomical variations proved by CT.[17] Involvement of ≥2 sinuses is a frequent observation compared to single sinus involvement.[28] However, Bolger *et al*. found the incidence in patients with sinus pathology was similar to that in persons studied for other reasons.[24] Few are not in support of this positive association as the mere presence of variants does not mean a predisposition to sinus inflammation; but in addition, one has to consider the presence of associated contributing factors. This cautions us to arrive at the conclusion by just considering the presence of variants.[25,29] This opinion is not shared by Yousem who claimed that the anatomical variants may be predisposing factors, depending on their size.[30] Our study population had anatomical variations as one of the major predisposing factors, >1 variant was seen in 72% of our patients; 2–3 variants in a patient was a common observation.

Maxillary sinus is the most frequently affected sinus due to its anatomy.[31] Maxillary sinus (54.3%) was the most affected while sphenoidal sinus the least (10%).[17] Mendiratta *et al*. reported that ostiomeatal complex (87.5%) and maxillary sinus (87.5%) were frequently involved.[10] Bolger *et al*. reported maxillary sinus involvement (77.7%) as the most frequent; posterior ethmoids (38.6%), frontal sinus (36.6%) were less frequent and sphenoid sinus involvement was still less (25.4%).[24] Among our patients, maxillary sinus was affected the most (62%), followed by ethmoid (48%), sphenoid (38%); only 36% patients had frontal sinusitis.

The prevalence of anatomical variation in PNSs varies widely among investigators. Differences in reported prevalence may be attributed to observer variation and racial variations. Deviation of nasal septum, concha bullosa, uncinate variations, and inferior turbinate hypertrophy were found to be the common variations reported.[1,9,28,32]

Septal deviation (58.5%) was common occurrence followed by concha bullosa (49.3%); hypertrophic ethmoidal bulla (32.8%), large agger nasi cells (24.3%), and Haller cells (22.8%) were the other frequent variations.[17] Mendiratta *et al*. though noted the same but in a reverse order of prevalence, i.e. agger nasi cells (80%), DNS (72.5%), and concha bullosa (47.5%).[10] Scribano *et al*. reported concha bullosa, septal spur, and deviations as the frequent variations in their study.[33] Contribution of anatomical variation of nasal turbinate in CS was evaluated using CT images of 384 patients. Concha bullosa was the most common variation while the bifid inferior turbinate was the least frequent occurrence.[34] Our study reports DNS as the most common variation (60%), followed by concha bullosa (38%), similar to the available reports.[10,17,33]

Similar observation was reported by Vincent and Gendeh who noted increased prevalence of concha bullosa among females and in Chinese and Indian ethnic group.[35] DNS (36%) and concha bullosa (30%) were common occurrence followed by sphenomaxillary plate (17%). Pneumatization of the UP (02%) was least frequent.[36] Pneumatization of the UP is considered to be an uncommon cause for CS.[37] Tuli *et al*. deny the role of UP in chronic rhinosinusitis[38] while Srivastava and Tyagi reported positive association between them.[39]

The middle turbinate may be paradoxically curved, i.e. bent in the reverse direction. This may lead to impingement of the middle meatus and thus leading to maxillary and ethmoid sinusitis. In this study, we observed that sinusitis occuring as a result of paradoxically curved middle turbinate in 18% of patients comparatively which was higher than the previous report (10%).[3]

Zinreich first observed that the UP may be lateralized or medialized. It can impair sinus ventilation especially in the anterior ethmoid, frontal recess, and infundibulum regions.[40] Medialized UP was most common occurrence (18%) while lateralized UP was less (4%). Pneumatized UP was infrequent (2%) in our patients similar to that reported by Bolger *et al*. (2.5%).[24] Sinusitis can result from a markedly medially bent or pneumatized UP with a corresponding area of extensive contact with the middle turbinate. In addition, the presence of combination of anatomic variations increases the proportion of pathogenic effect than the single variant.[40]

Haller's cells are ethmoid air cells that project beyond the limits of the ethmoid labyrinth into the maxillary sinus. They are considered as ethmoid cells that grow into the floor of orbit and may narrow the adjacent ostium. Greater proportion of patients (21%) had HC in our study compared to that reported by Kennedy and Zinreich[41] and Zinreich.[27] The incidence in this study is less than that reported by Bolger *et al*. (45.9%)[24] and Asruddin *et al*. (28%).[42] Haller cells, though comparatively less frequent occurrence, do contribute to the development of CS. Kainz *et al*. noted that 8.14% of their patients had at least unilateral presence of Haller cells. They traced the origin of HC to anterior ethmoidal cells in 88%. There was female preponderance (11.9%) compared to men (4.9%).[43] Our report on HC (21%) is higher than the previous reports.[43]

Agger nasi cells lie just anterior to the anterosuperior attachment of the middle turbinate and frontal recess. These can invade the lacrimal bone or the ascending process of maxilla. Its presence varies with greater prevalence reported by Bolger *et al*. (98.5%)[24] followed by Davis (65%);[44] Dua *et al*.[45] and Bolger *et al*.[24] quoted in 1991 that Mosher *et al*. reported that 40% of their patients had agger nasi cells. Lower prevalence of 10%–15% was reported by Messerklinger.[46] These cells were present in 33% of patients in our study.

We report the presence of ethmoidal bulla (20%), onodi cells (10%) in considerable number of patients signifying the contribution of these anatomical variations in the development of CS.

Optic nerve was classified into four types based on their course and association with the adjacent sphenoid sinus. Type I optic nerve was more frequent, more so on the left side (84%) compared to the right side (76%) and Type IV optic nerve involvement was infrequent. In contrast, Delano *et al*. found that 85% of optic nerves associated with a pneumatized anterior clinoid process were of Type II or Type III configuration, and 77% were dehiscent.[4] These observations signify the requirement of early intervention to prevent disease complications.

Dehiscence of lamina papyracea, cribriform plate, and carotid canal wall have a lesser incidence rate but are very important to be identified, and we found that only 2% of our patients had dehiscence of lamina papyracea whereas cribriform plate and carotid canal wall were not seen in any of our participants.

Leunig *et al*. studied the anatomical variations in 641 patients using multiplanar CT. They reported that anatomical variations in frontoethmoidal cells were more frequent. Of the four types of Kuhn cells, Type I was more frequent and Type IV was least frequent. Agger nasi cells were most prevalent (80%). Concha bullosa (22%) and Haller cells (16%) were less frequent. Pneumatized UP (8.8%) and onodi cells (8.4%) were also reported.[47] Liu *et al*. reported that 81.14% patients in their study had anatomical variation. They reported higher prevalence of deviation of uncinate (45.27%), pneumatized middle turbinate (34.85%), and large ethmoidal bulla (30.30%) along with less common presence of large agger nasi (0.70%) and Haller cell (1.00%).[2]

Clinical correlation of the symptoms and CT findings has proved to be useful in assessing the symptom severity which enables the otolaryngologist in better disease management.[48] Mohebbi *et al*. ruled out the relationship between the degree of DNS and severity of symptoms.[49] These observations call for careful clinical correlation of the CT findings for optimal therapeutic outcome, and authors too agree to this statement.

Vining is of the opinion that CT findings provide little guidance in the management of the CS.[50] However, our study contradicts this observation.

CONCLUSION

CT plays an important role in the visualization of anatomical variations in PNSs, and our study reemphasizes the concept that anatomical variations particularly in the ostiomeatal complex are the key factors in the causation of CS. CT of the PNSs has improved the visualization of PNS anatomy and has allowed greater accuracy in evaluating PNS disease. It helps in evaluating the complex anatomy of PNSs which is not possible with plain radiographs. We suggest that the radiologist must pay close attention to anatomical variants in the preoperative evaluation and help avoid possible complications and improve success of management strategies.

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Conflicts of interest
There are no conflicts of interest.

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