The Journal of Laryngology and Otology
March 1991, Vol. **105**, pp. 181–185

CT of the paranasal sinuses and functional endoscopic surgery: a critical analysis of 100 symptomatic patients

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Abstract

CT scans of 100 patients from the Rhinology Clinic at the Royal National Throat, Nose and Ear Hospital were reviewed in order to test the precepts forming the basis of functional endoscopic sinus surgery, especially as they relate to the radiological investigation. These were: (a) the site of origin of sinus infection. (b) The relevance of certain anatomical variants in the middle meatus to sinus infection and (c) The use of CT as the radiological method of diagnosis in all cases.

Obstruction in the middle meatus and ostiomeatal complex was associated with an increased incidence of opacity in the sinuses but the primary site of disease was not established: the concept that sinus disease takes origin in the middle meatus was not proven.

Anatomical variants in the middle meatus were not associated with an increase in sinus opacity and there was no evidence that these anomalies have any effect on sinus disease by causing middle meatal stenosis.

The radiological assessment of patients with inflammatory naso-sinus disease should start with plain X-ray. CT is unnecessary as a routine examination. It should be reserved for the pre-operative assessment of patients for endoscopic surgery, its main function being to show important anatomical landmarks.

Introduction

In 1978, Messerklinger published the first comprehensive account in English of the technique of naso-sinus endoscopy and its application to the treatment of chronic and recurrent rhinosinusitis. Previously the same author (Messerklinger, 1967) in his study of the drainage of the frontal sinus had identified muco-ciliary backflow into the sinus cavity from the frontal recess, providing a potential route for the introduction of infection. He also demonstrated a similar retrograde flow into the maxillary antrum from the middle meatus. (Messerklinger, 1978). Based upon this research Messerklinger devised endoscopic surgical procedures for the treatment of sinus infections. His method has been described as functional endoscopic sinus surgery. (Kennedy *et al.*, 1985). Developments of the surgical technique have been largely the work of Stammberger (1985; 1986) and Kennedy *et al.* (1985) and the imaging requirements for the procedure have been described by Zinreich *et al.* (1987).

Collectively these authors advance the following precepts:

1. Infection in the paranasal sinuses usually starts in the middle meatus of the nose and spreads via the frontal recess, anterior ethmoids and infundibulum (together referred to as the ostiomeatal complex) to the frontal sinus and maxillary antrum. Infection in the latter sinuses is therefore of a secondary nature. It is said that certain anatomical variants predispose to infection in the middle meatus by causing stenosis and obstruction: these are concha bullosa, a bent uncinate process, an over-pneumatised ethmoid bulla, a paradoxical turbinate (i.e. one that is curved in the opposite direction to that normally found), Haller cells and agger nasi cells.
2. Based on this concept, endoscopic surgery aims to eliminate disease in the primary site i.e. the ostiomeatal complex and allow resolution of the secondary infection in the larger sinuses. 'With usually very limited procedures diseased ethmoid compartments are operated on, stenotic clefts widened and prechambers to the frontal and maxillary sinuses freed from disease'. (Stammberger, 1990).
3. Pre-operative diagnosis for these patients is based upon a combination of endoscopy of the lateral nasal wall with X-ray studies using coronal CT. Plain sinus X-rays are considered by these authors to be of little value in the work-up of these patients. The reason given is that they are frequently not able to demonstrate the underlying causes for chronic or recurring sinusitis in the clefts of the anterior ethmoid cells (Stammberger, 1990).

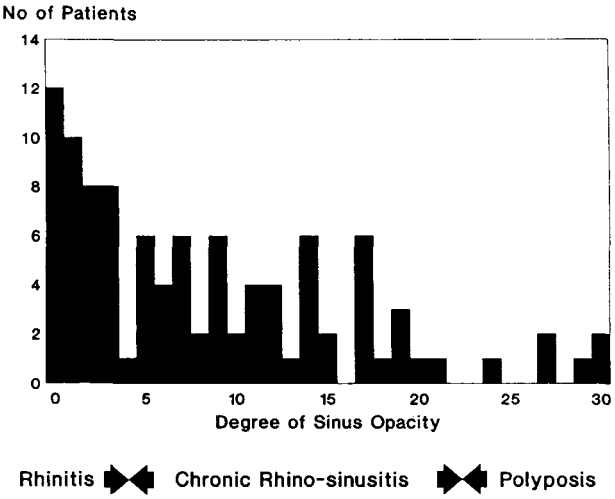
In order to test these principles, especially as they relate to the radiological investigation of patients with persistent nasal obstruction and rhinorrhoea as the main presenting features, the CT scans of 100 consecutive patients from the Rhinology Clinic at the Royal National Throat Nose and Ear Hospital have been reviewed.

Material and method

One-hundred patients from the Rhinology Clinic were examined by biplane CT. Contiguous sections of 4 mm were obtained in the axial and coronal planes to

TABLE 1

THE DEGREE OF OPACITY AS SHOWN BY CT WAS SCORED FOR EACH SINUS CAVITY ON THE FOLLOWING BASIS: 0 = NORMAL SINUS; 1 = MINOR MUCOSAL THICKENING; 2 = MAJOR MUCOSAL THICKENING; 3 = TOTAL OPACITY OR FLUID LEVEL. THE TOTAL FOR ALL SINUSES IN THE INDIVIDUAL PATIENT RANGED FROM 0 TO 30 POINTS. THE DEGREE OF OPACITY WAS PLOTTED ON THE HISTOGRAM AGAINST THE NUMBER OF PATIENTS WITH EACH SCORE FROM 0 TO 30. IT CAN BE SEEN THAT THE PATIENTS IN THE SERIES COULD BE GROUPED INTO THREE CATEGORIES DEPENDING UPON THE DEGREE OF OPACITY PRESENT AND CORRESPONDING APPROXIMATELY TO THE THREE PRINCIPAL DIAGNOSES: RHINITIS; CHRONIC RHINOSINUSITIS; AND NASAL POLYPOSIS.



include the nose and paranasal sinuses. Window widths of 2000–4000 Hounsfield units were employed. The CT scans were examined for the following features:

(1) The extent of sinus opacity in the individual sinus cavities. Each sinus cavity was scored from 0–3 depending upon the degree of opacity present (Table I). For this exercise, the anterior and posterior ethmoid cells were treated as separate entities; they are functionally different and are separated anatomically by the lamellar attachment of the middle turbinate. Thus, ten sinus compartments were scored for each individual patient and total scores ranged from 0 to 30.

(2) The incidence of anatomical variants affecting the ostiomeatal complex and middle meatus were recorded and the degree of sinus opacity associated with them determined.

(3) The degree of mucosal contact and obstruction in the frontal recess, infundibulum and middle meatus was assessed both in the coronal and axial planes on a simple positive/negative basis, so that scores of zero, one or two plus were recorded for each separate area (Tables II, III & IV).

(4) In addition, the plain X-rays for 72 patients were available for inspection so that these could be directly compared with the findings of Computed Tomography.

TABLE II

THE TABLE RELATES THE DEGREE OF OPACITY IN THE FRONTAL SINUSES AND ANTERIOR ETHMOID CELLS (USING THE SCORING SYSTEM DESCRIBED IN TABLE I) TO OBSTRUCTION IN THE FRONTAL RECESS DEMONSTRATED ON CT

	Obstruction in Frontal recess		
	0	+	++
Average opacity in Frontal Sinus	0.22	0.71	1.34
Average opacity in the Anterior Ethmoids	0.26	1.06	2.08

Results

1. Eighty-eight per cent of the patients showed some opacity of the sinuses: in 83 per cent the maxillary antra were affected; the ethmoids in 70 per cent overall (63 per cent anterior ethmoids, 57 per cent posterior ethmoids); the frontal sinuses in 60 per cent, and the sphenoid sinuses in 49 per cent.

Each individual patient was scored for the degree of sinus opacity on CT and the results recorded on a histogram (Table I). The series showed a trimodal distribution consistent with the three principal clinical conditions encountered: allergic rhinitis, chronic rhinosinusitis, and gross nasal polyposis.

2. The incidence of anatomical variants said to contribute to middle meatal stenosis was as follows:

Concha bullosa ..... 24 per cent
Paradoxical middle turbinate..... 15 per cent
Over-pneumatised bulla ethmoidale..... 18 per cent
Bent uncinate process..... 21 per cent
Haller cells ..... 15 per cent
Agger nasi cells ..... 14 per cent

Collectively these variants were present in 62 per cent of the series and were associated with an average opacity in the sinuses of 6.3 points. This was less than the score recorded for the remaining patients in the series, without an anatomical anomaly; they scored an average of 8.3 points (excluding patients with nasal polyposis).

The scores for the individual variants were as follows: concha bullosa 6.1; paradoxical middle turbinate 5.0; over-pneumatised bulla ethmoidale 7.1; bent uncinate process 5.71.

Collectively and individually patients with these anomalies were not therefore associated with any increase in sinus opacity above that found in patients without an anatomical abnormality.

3. The relationship between obstruction in the frontal and antral pre-chambers, (the frontal recess and infundibulum) and opacity in the frontal sinuses, anterior ethmoid and maxillary antrum is shown in Tables II and III. It can be seen that in all instances increased opacity in the sinuses was associated with increased obstruction in the pre-chamber through which the sinus drained into the middle meatus. There was, however, nothing to indicate which of the two elements initiated the changes.

Table IV shows the relationship between any degree of obstruction in the middle meatus and overall opacity in the sinuses. It can be seen that obstruction in the middle meatus was associated with nearly three times the opacity in the sinuses in comparison with that found in patients with an unobstructed middle meatus. But

TABLE III

THE TABLE RELATES THE DEGREE OF OPACITY IN THE MAXILLARY ANTRA AND ANTERIOR ETHMOIDS TO OBSTRUCTION IN THE INFUNDIBULUM.

	Obstruction in the Infundibulum		
	0	+	++
Average opacity in the Maxillary Antra	0.49	1.0	2.08
Average opacity in the Anterior Ethmoids	0.43	1.18	1.95

TABLE IV

USING THE SCORING SYSTEM DESCRIBED FOR TABLE I, IT CAN BE SEEN THAT OBSTRUCTION IN THE MIDDLE MEATUS SHOWN ON CT IS ASSOCIATED WITH NEARLY THREE TIMES THE DEGREE OF OPACITY RECORDED FOR PATIENTS WITHOUT OBSTRUCTION

Relationship of Obstruction in the Middle Meatus to Sinus Opacity	Score
patients with obstruction	14.8 av
Patients without obstruction	5.0 av

again, there was no evidence to establish which element was causative.

In addition septal deviation of 3 mm or more was associated with an increase in sinus opacity above the average for the series as a whole. More detailed assessment was not possible because of a non-standardised technique and variable hard copy size.

4. Seventy-two patients in the series were examined by plain X-ray in addition to CT scan so that a direct comparison of the two techniques was possible. Plain X-ray consisted of three films: standard occipito-mental and occipito-frontal films, and a lateral view using high Kilovoltage (150 or above) and 3 mm brass filtration. This allows better demonstration of the air spaces in the sinuses by partial elimination of the overlying bone structures and is particularly useful for demonstrating the ethmoid labyrinth.

Only those patients who had both examinations within a time span of four weeks were accepted for the comparison, and the plain X-ray examinations were scored for sinus opacity in a like manner to that employed for CT in Table I. Overall there was a 92.5 per cent correlation between plain X-ray and CT. The average score for the patients in the plain X-ray series being 6.3 points in comparision with a score of 6.8 points for CT. The ethmoids are generally regarded as being the least well demonstrated of the sinuses on plain X-ray, but in this series there was an 86 per cent correlation with CT both for the ethmoid labyrinth as a whole and for the anterior ethmoid cells alone.

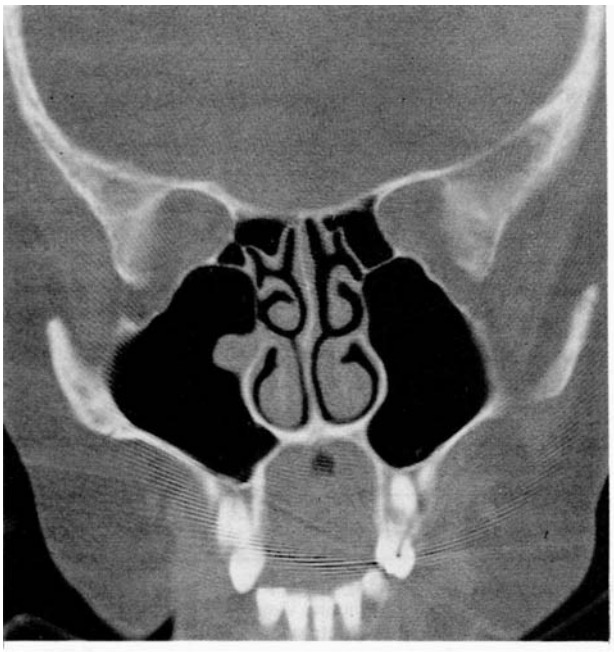


FIG. 1

Coronal CT scan showing clear sinuses except for a small polypoid swelling of the mucosa in the right antrum. With this insignificant degree of change in the sinuses the patient would be placed in the rhinitis group provided the symptomotology was compatible with this diagnosis.

Discussion

It is now generally accepted that CT is the optimum imaging method of demonstrating simple inflammatory disease in the paranasal sinuses. Previous studies have shown poor correlation of plain X-ray with CT. Davidson *et al.* (1989) found a lack of concordance between plain X-ray and CT of approximately 25 per cent for the maxillary and ethmoid sinuses and 40 per cent for the nasal cavities. They concluded that plain films are unreliable and no longer routinely indicated for the evaluation of paranasal sinus disease. They suggested that clinical assessment be used to evaluate acute sinus infection, and CT used for the investigation of persistent and chronic sinus disease refractory to medical therapy.

In the nose and paranasal sinuses there are two areas where plain X-rays are said to be inadequate: in the anterior ethmoids and in the nasal cavity. In this series plain X-ray showed an 86 per cent correlation with CT in comparison with a 92.5 per cent correlation for the sinuses overall (see above). Despite the use of a high KV lateral film which has the effect of partially obliterating the overlying bone structures, allowing better visualisation of the anterior ethmoids, plain X-ray cannot provide the plan view of the ethmoid labyrinth of CT, which makes it the standard by which other techniques must be judged. In the series there was a tendency to overdiagnose anterior ethmoid opacity on plain X-ray and this was the major shortcoming in comparision with CT. There were however only two false negatives in the 72 patients reviewed. From this it is pertinent to ask if it is

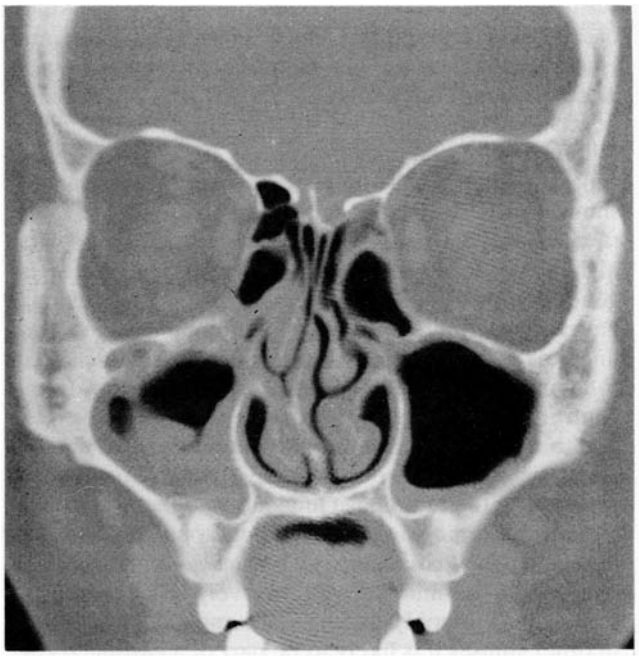


FIG. 2

Coronal CT scan showing extensive mucosal thickening in the sinuses compatible with a diagnosis of chronic rhinosinusitis.

https://doi.org/10.1017/S0022215100115300 Published online by Cambridge University Press

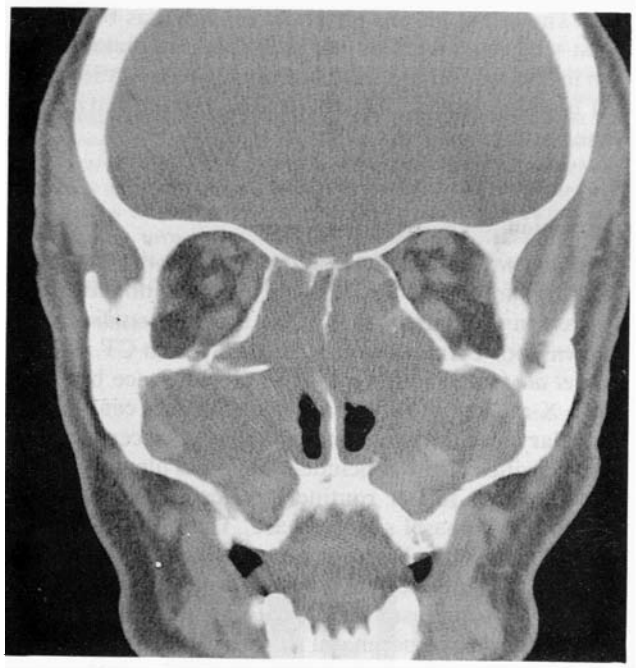


FIG. 3

Coronal CT showing the typical changes of gross nasal polyposis. There is total clouding of the sinuses and the upper part of the nasal cavity. The bony walls and nasal septum are eroded and the ethmoid labyrinth is expanded laterally.

important to miss minimal opacity in the anterior ethmoids in a small minority of patients.

In a previous publication (Lloyd, 1990) a control series of CT scans were reviewed in relation to endoscopic naso-sinus surgery. There was a surprisingly high incidence of asymptomatic sinus disease in this group, opacity in one or more sinuses being recorded in 39 per cent. Other authors have found a similar degree of change in control series. Havas *et al.* (1988) recorded 42.5 per cent of abnormality and a more recent study based on magnetic resonance imaging (Cooke and Hadley, 1991) ahowed incidental sinus abnormalities in 37.5 per cent of 483 images examined. The highest incidence of asymptomatic change has been found in the ethmoid cells: 28.4 per cent (Havas *et al.*, 1988); 28 per cent (Lloyd, 1990). In the latter series 15 per cent showed opacity isolated to the ethmoids, an incidence three to four times that of the symptomatic group. The high incidence of clouded ethmoid cells thus found in the general population, makes it difficult in the individual patient to attribute symptoms to minimal changes, confined to the ethmoid cells. Such changes are in fact likely to be irrelevant except in a minority of patients. In the control series it is probable that most of the opacity is due to the residuum of an old ethmoiditis rather than a reservoir of infection or an active disease process—a situation to the radiologist analogous to the presence of pleural thickening on a chest radiograph (Lloyd, 1990). Some of these patients may also have simple polypoid swelling of the mucosa without overt infection. However, when ethmoid clouding is accompanied by changes in other sinuses it is likely to be part of a chronic recurring sinusitis; and this is a situation that is readily diagnosible by plain X-ray. In summary the radiological sign of opacity of a few anterior ethmoid air cells is likely to represent a chronic sinusitis or nasal polyposis when found in association with moderate or major degrees of opacity in the remaining sinuses, but is unlikely to be of any significance when seen in isolation. In the former circumstance adequate diagnosis can be made by plain X-ray; in the latter it matters little if a few clouded air cells in the anterior ethmoids are missed.

In contrast to the adequate demonstration of the paranasal sinuses by plain X-ray , the nasal cavity is poorly shown and only gross pathology usually recognized. Relatively large masses may be missed in the middle meatus and in the context of inflammatory disease the ostiomeatal complex cannot be evaluated; nor is it possible to recognize the normal anatomical variants in the middle meatus. However the need to do this is to be questioned in the light of the results described above in which these normal variants were not associated with an increase in sinus opacity in relationship to patients without an anomaly; in fact the latter showed a thirty per cent increase in comparison.

Some form of tomography, either conventional or CT will however be needed to show obstruction in the middle meatus and ostiomeatal complex if this cannot be determined by endoscopic inspection. From Tables II–IV, it is clear that the degree of sinus opacity closely relates to the degree of obstruction in the middle meatus and ostiomeatal complex, although which element is the prime cause is not established. In this respect the work of Flottes *et al.* (1960) has been quoted previously concerning the pathophysiology of sinusitis (Lloyd, 1990). These authors postulated a vicious circle in which persistent sinus infection and ostial obstruction interact, the one giving rise to the other and *vice versa*. In these circumstances, the primary cause is largely irrelevant in terms of treatment, since relief of the middle meatal obstruction by endoscopic surgery is likely to abort the infection and reduce the recurrent rate whatever the site of origin.

The results of the CT investigations performed on the 100 patients under review, showed that they could be divided into three general groups based upon the degree of sinus opacity: rhinitis; chronic rhinosinusitis; and gross nasal polyposis, (Table I; Figs. 1, 2 & 3). In a like manner, these three categories can be recognized on plain X-ray. The rhinitis group present with normal sinuses or with minimal degrees of mucosal thickening in one or two sinus cavities; the chronic rhinosinusitis patients will have substantial mucosal thickening in multiple sinus cavities some showing total opacity; gross

TABLE V

THE RESULTS OF RADIATION MONITORING SHOWS THAT BIPLANE CT OF THE PARANASAL SINUSES GIVES NEARLY 185 TIMES THE DOSE TO THE SENSITIVE LENS AND CORNEA THAN THAT RECORDED FOR PLAIN X-RAY

Radiation to the Eye in Sinus X-ray Studies mSv			
	Plain X-ray		
Left Eyelid	Occipito-mental view		0.069
	Occipito-frontal view		0.057
	Lateral view		0.188
		Total	0.314
	Computed Tomography		
Left Eyelid	Axial sections		44.816
	Coronal sections		13.191
		Total	58.007

https://doi.org/10.1017/S0022215100115300 Published online by Cambridge University Press

nasal polyposis gives the typical plain X-ray appearance of total opacity of all sinuses associated with loss of translucence in the upper part of the nasal cavity, sometimes associated with decalcification of the sinus walls, and in the younger age group expansion of the ethmoid labyrinth (Lund, and Lloyd, 1983; Lloyd, 1975). Superimposed infection in both the rhinitis group and in nasal polyposis means that there is no absolutely sharp distinction between these categories but the large group of patients with allergic rhinitis can be readily diagnosed clinically in combination with plain X-ray; the latter should therefore be the initial radiological investigation since the rhinitis patients will not as a rule require computed tomography.

The one clear reason for performing CT in patients with inflammatory sinus disease is to reduce the complication rate of functional endoscopic sinus surgery by identifying anatomical landmarks pre-operatively. This demands axial CT since the relationship of the lamina papyracea and sphenoid sinuses to the optic nerve and carotid canal are best demonstrated in this plane. In this respect there is an imporant caveat for surgeons using CT for this purpose: the radiation dose to the sensitive lens and cornea is particularly high when axial CT sections are used. Careful positioning of the patient in the scanner may reduce the dose but the problem is very often ignored by the technician performing the scan so that doses as high as 40–50 millisieverts may be recorded Table V. At a time when there is much concern for the amount of radiation received from diagnostic X-ray procedures this amount of radiation is unacceptably high unless there is a compelling diagnositic reason for using CT. A recent publication (National Radiological Protection Board, 1990) has emphasized the high radiation implications of CT examinations and suggests that this method of imaging has become one of the major contributors to an increased population dose from medical radiology.

Conclusions

1. An increased incidence of opacity of the sinuses shown by CT was associated with obstruction in the middle meatus, frontal recess and infundibulum on the side affected and the degree of obstruction roughly proportional to the extent of the opacity. However the primary site of disease was not established.

2. The anatomical variants in the middle meatus (concha bullosa, paradoxical middle turbinate, bent uncinate process, over-pneumatised bulla ethmoidale, Haller cells and agger nasi cells) were not associated with any increased sinus opacity; there was no evidence therefore that these anomalies have any effect on sinus disease by causing middle meatal stenosis.

3. The radiological investigation of patients with inflammatory naso-sinus disease should start with plain X-ray. Apart from helping to exclude more serious sinus disease, these films allow the radiologist to recognize gross nasal polyposis, and eliminate non-infected allergic rhinitis from the differential diagnosis. At this stage CT is contraindicated because of radiation exposure to the lens and cornea. In the majority of inflammatory conditions in the paranasal sinuses, CT should be reserved for the pre-operative assessment of patients for endoscopic sinus surgery, its main function being to show important anatomical landmarks.

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Key words: Computerised tomography; Paranasal sinuses; Endoscopic surgery