

# A comparative study between ciliary count and the degree of opacity of paranasal sinus CT scans in chronic sinusitis pre and post FESS

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## Abstract

**Objective:** To investigate the relationship between the extent of sinus disease in chronic sinusitis as detected radiologically by computed tomography (CT) scan and the population of cilia (ciliary area) both before and after functional endoscopic sinus surgery (FESS). In a simple way this is a trial to statistically prove that the CT scan could be a valid indicator and a mirror of the histological status of the sinus mucosa.

**Design:** Twenty adult patients were enrolled in this study. Radiological extension of the sinus disease was quantitated using the classification proposed by Kennedy in 1992 and the ciliary population was studied using scanning electron microscopy and image analysis softwares.

**Results and conclusion:** The more advanced the sinusitis, as evidenced by CT scans, the more the expected reduction in the ciliary area (CA) and in the ciliary count. But after FESS the degree of ciliary regeneration does not depend statistically on the radiological condition of the sinuses and the degree of opacity prior to intervention, i.e. a statistically valid inverse relationship exists between the radiological stage of sinusitis and the ciliary population pre-operatively but the same relation does not extend to the ciliary population post-operatively.

**Key words:** Sinusitis; Tomography, Computed; Scanners; Endoscopic Surgical Procedures; Cilia; Scanning Electron Microscopy

## Introduction

Drainage and ventilation are the two most important factors in the maintenance of normal physiology of the paranasal sinuses and their mucous membrane.<sup>1</sup> Nasal mucociliary clearance is a fundamental function required to maintain the health and defence of the nose.<sup>2</sup>

Obstruction of the osteomeatal complex is a significant factor in the development of chronic sinusitis,<sup>3</sup> and the removal of the obstructed osteomeatal complex is the primary goal in functional endoscopic sinus surgery (FESS).<sup>4</sup>

The population of cilia in the paranasal sinuses is known to drop with chronic sinus infection due to destruction of the cilia by the chronic inflammatory process, and to increases of squamous metaplasia, microvillous cells and goblet cells, which leads to a decrease in mucociliary clearance and to the retention of secretions, and a vicious circle is established. FESS is associated with ciliary

regeneration and an increase in the number of cilia in the sinuses.<sup>5-7</sup> The population of cilia in the paranasal sinus mucosa before any sinus surgery is an important factor in the creation of effective drainage of the paranasal sinuses post-operatively, so it is always important to try to investigate and predict the count of cilia in paranasal sinuses before any sinus operation. Counting cilia on the surface of sinus mucosa involves invasive, costly, time-consuming and complicated methods.<sup>5,6</sup>

Here we try to predict the number of cilia on the surface of sinus mucosa using a simple diagnostic method, namely the computed tomography (CT) scan, and we try to find a link between the radiological stage of sinus disease and (1) the population of its cilia pre-operatively, and (2) the post-operative regeneration potential of the cilia so that we can use the CT scan as a histological predictor in evaluating patients with chronic sinusitis.

## Patients and methods

### Patient population

Twenty adult patients were enrolled in this study: there were nine males and 11 females, with ages ranging from 17 to 53 years (mean 35 years). Chronic sinusitis was defined in our patients as inflammation of the nasal and sinus mucosa with persistent mucous or mucopurulent nasal discharge for more than three months that was resistant to repeated antimicrobial therapy and antral irrigation.<sup>8</sup> The patients were diagnosed as having chronic sinusitis from their clinical history, nasal endoscopic examination and CT scan. Written consents were taken from all patients to share in the study and to perform surgery.

### CT assessment of the disease

In our study we used the classification proposed by Kennedy in 1992<sup>3</sup> in which he classified chronic sinusitis into four stages:

- Stage I Anatomical abnormalities, all unilateral sinus disease or bilateral disease limited to ethmoids.
- Stage II Unilateral ethmoidal disease with involvement of two or more dependent sinuses on each side.
- Stage III Bilateral ethmoidal disease with involvement of two or more dependent sinuses on each side.
- Stage IV Diffuse sinonasal polyposis.

Coronal non-contrasted CT scans were taken for the patients immediately after a 10-day course of systemic antibiotics; we took the sections at 5 mm thickness using 200 window widths and 20 window levels, and all the measurements were done in the cuts at the level of sinus ostium.

FESS was performed in all patients under general hypotensive anaesthesia, using the technique described by Stammberger and Hawke.<sup>9</sup> In 12 out of 20 cases (60 per cent) septal surgery was performed as an integral part of the FESS procedure, to correct septal deflections and to facilitate access to the osteomeatal complex region. Pre-operative local decongestants and antihistamines were given for one week to prepare the nose for the surgery; and post-operative care and medications were standard and uniform for all patients, which consisted of first generation cephalosporines for 10 days with frequent nasal irrigation and suction in the first two weeks following surgery.

### Counting ciliary population

To count the number of cilia in the specimens we took the following steps:

- (1) Specimens were collected from the patients during FESS from the region of the maxillary sinus ostium using fine-tipped forceps so as not to crush the cilia. While taking the biopsies, the mucosa looked macroscopically very variable and there was no consistent gross picture, in

some cases the mucosa looked hyperplastic or even polypoidal and in others the mucosa was very thin and atrophic. Sometimes mucoid or even purulent exudate was present on the surface of the mucosa but cultures were not taken from it.

- (2) Specimens were washed immediately in saline to remove the surface mucus. Preparation for scanning electron microscopy then included: prefixation with one per cent glutaraldehyde and sodium cacodylate 0.3, sequential dehydration in graded ethanol (50, 70, 80, 90, 95 and 100 per cent), substitution with isoamyl acetate, critical point drying with carbon dioxide, and sputter coating with gold.
- (3) Specimens were studied using scanning electron microscopy (JSM-T200, JEOL Ltd, Tokyo, Japan).
- (4) Computer software (image analysis; Aquitus 1) was utilized to sweep the electron microscopy images and to calculate the ciliary area (CA) which is defined as the percentage of the area occupied by cilia on the surface of the epithelium in the studied image. The CA of a sample was expressed as the mean of the ciliary area values in five pictures taken at random for each specimen. This method was previously used by Bassiouny *et al.* 2003,<sup>5</sup> Guo *et al.* 1997,<sup>6</sup> Guo *et al.* 1998<sup>7</sup> and Atef and Ayad 2004<sup>10</sup>, and indeed we consider it the most accurate method for counting cilia.
- (5) Patients were then re-biopsied a variable period of 6–12 months (average 8.1 months) after the FESS.

### Statistical analysis

Spearman's coefficient of rank correlation was used to evaluate the correlation between the CA and the radiological stage of sinusitis. The significance of the CA according to the different degree of opacity present in the maxillary sinus was evaluated by using Wilcoxon's signed-ranks test. At  $p < 0.05$  comparisons were considered significant.

## Results

The distribution of our studied cases according to the radiological stage of the disease is shown in Figure 1.

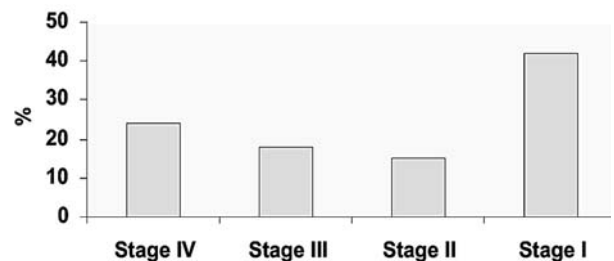


FIG. 1

Distribution of cases according to radiological stage of sinusitis.

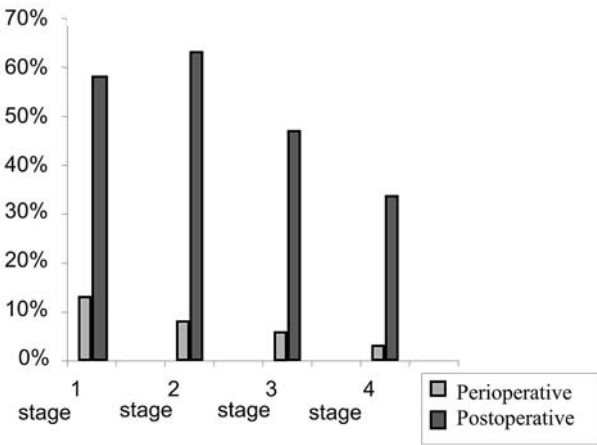


FIG. 2

The relationship between ciliary area and CT stage of sinusitis in the peri-operative (■) and post-operative (■) biopsies.

The CA in the peri-operative biopsies (biopsies taken during operation from maxillary sinus ostium) ranged from 0.28 to 29.34 per cent with a mean of 11.11 per cent and a standard deviation of 9.4.

The CA in the follow-up biopsies taken from the same area ranged from 32.7 to 64.6 per cent with a mean of 51.91 per cent and a standard deviation of 11.31.

There was a statistically significant inverse relation between the CA at the maxillary sinus ostium before FESS and the radiological stage of sinusitis, that is to say that the more the opacity and the more the increase in the radiological stage the less the values of the CA and the more the ciliary loss ( $p < 0.05$  and the coefficient carrier for the relation between the CA of the maxillary sinus ostium and the radiological stage was 0.676 while the critical value for the same relation was  $\pm 0.466$ ) (Figure 2).



FIG. 4

The scanning electron microscopy image of the same case taken during the FESS showing widespread ciliary destruction and epithelial metaplasia.

On the contrary we could not achieve a statistically significant relationship between the radiological stage of the disease and the CA at the maxillary ostial region post-operatively, which means that the ciliary population and the CA (6–12) months post-operatively (regenerating cilia) do not depend on the radiological stage of the sinusitis before the intervention, and that the more opaque the sinuses are pre-operatively as shown in the CT scans, this is not necessarily associated with lesser power of regeneration ( $p > 0.05$  and the coefficient carrier for the relation between the CA of the maxillary sinus ostium post-operatively and the radiological stage is 0.143 while the critical value for the same relation is  $\pm 0.466$ ) (Figures 3, 4 and 5).

In brief, pre-operative CT can give us an idea about the pre-operative count of cilia in the sinuses but cannot predict the post-operative regeneration power.



FIG. 3

Computed tomography (CT) scan of one of our cases prior to surgical intervention showing stage (2) disease.

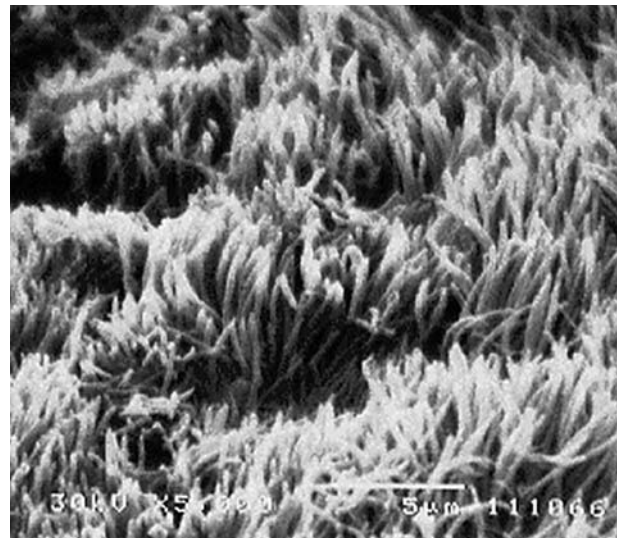


FIG. 5

The scanning electron microscopy image of the same case eight months after FESS showing widespread ciliary regeneration, all beating in one direction.

## Discussion

Mucociliary clearance is important in the drainage of the nose and the paranasal sinuses. As the mucociliary clearance is closely correlated to the population of cilia, any reduction in the population of cilia may impair mucociliary clearance and result in a retention of secretions in the infected sinuses. The number and condition of cilia in the nose and paranasal sinuses are important factors in the success of FESS, and it is well known that the results of FESS are not so good in cases of primary ciliary dyskinesia. The thickness of antral mucosa is closely related to the quantity of inflammatory cells in chronic sinusitis.<sup>11</sup>

Counting cilia on the surface of sinus mucosa necessarily involves invasive, costly, time-consuming and complicated methods.<sup>5,6,10</sup>

In our present study we tried to predict the number of cilia on the surface of sinus mucosa using a simple diagnostic indicator, namely the CT scan. This work was previously tried by Guo *et al.*<sup>7</sup> but they evaluated the CT in a different way from our method. While we used the radiological classification proposed by Kennedy<sup>3</sup> they utilized two methods: one reported by Min *et al.*<sup>12</sup> and the other reported by Vander Veken *et al.*<sup>13</sup> In the first method, an imaginary line from the uppermost lateral wall to the lowest point of the maxillary sinus was drawn on the CT. The thickness of the opacity was measured at the midpoint perpendicular to the line. In the second method, the maxillary sinus opacity was divided into four stages. In degree 1, the soft density area occupied 0–25 per cent of the maxillary sinus; in degree 2, the density involved 25–50 per cent of the sinus; in degree 3, the density covered 50–75 per cent of the sinus; and in degree 4, 75–100 per cent of the sinus was dense.

In our work, specimens were taken from the region of the maxillary sinus ostium as this is the key area in the pathogenesis of chronic sinusitis, and the CA in these peri-operative specimens ranged between 0.28 per cent and 29.34 per cent, while after the follow-up period the CA ranged between 32.7 per cent and 64.6 per cent. Halma *et al.* reported that the density of the ciliated cells in the normal population was very high inside the maxillary sinus, ranging between 91.3 per cent and 97.1 per cent except at the ostium of the maxillary sinus where it ranged between 47 per cent and 53 per cent.<sup>14</sup>

In our study we found valid statistical evidence that the greater the opacity of the paranasal sinus in the CT the less the CA and ciliary count in the specimens taken during the operation, while we could not achieve any statistical relation between the radiological stage of the disease and the ciliary count 6–12 months after the operation. This implies that the CT scan could be a useful guide and indicator to the number of cilia in the paranasal sinuses before surgical intervention but cannot predict the regeneration potential of paranasal sinus cilia after FESS; and that the more opaque the sinuses are on CT scans the less the number of cilia inside the sinuses, which is not true for the number of cilia 6–12 months later.

These results fit well with the work of Guo *et al.*,<sup>7</sup> but with three main differences:

- (1) Guo *et al.* studied only the first part of our work; they studied the relationship between the radiological state of the maxillary sinus and the ciliary count inside the maxillary sinus immediately before the FESS but did not extend their study to the relationship between the radiological state of the disease and the CA of the sinuses after the follow-up period, i.e. they did not study whether the regenerating power of the sinus cilia was related or affected by the radiological state of the sinuses as we did. Our work additionally makes a very important point: when discussing the possible results of FESS, the degree of opacity in the CT should not be taken as a predictor of success or failure.
- (2) Guo *et al.* studied the relationship only inside the maxillary sinus, as they took the biopsies from the maxillary sinus superolateral wall and only did the opacity measurements on the maxillary sinus. By contrast we included all the sinuses in our work as we followed the classification of Kennedy which includes all the sinuses, and we took our biopsies from the maxillary sinus ostium which is the key point in the pathogenesis of chronic sinusitis and is affected by the condition of the sinuses in each case.
- (3) Guo *et al.* studied the CT scans at the level of the ostium. When taking the biopsy they took it from the superolateral wall on the contrary while we took our biopsies from the ostium of the maxillary sinus and studied the CT scan at the same level.

- **This study investigates the relationship between ciliary dysfunction and severity of sinusitis as assessed by pre-operative sinus CT scan using the Kennedy staging system**
- **Severe disease on CT scan was associated with more advanced ciliary dysfunction, as measured by ciliary area and ciliary count with scanning electron microscopy**
- **Post-operative regeneration of ciliary function after functional endoscopic sinus surgery was independent of pre-operative CT score**

## Conclusion

Pre-operative CT scan can be a reliable and valid indicator to the number and count of cilia in the paranasal sinuses prior to FESS but cannot and should not be taken as an indicator of the regeneration potential of the ciliary membrane of the paranasal sinuses after FESS.

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