Original Paper

ORL

ORL 1998;60:202–205

Received: October 21, 1997
Accepted after revision: December 1, 1997

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Ciliary Beat Frequency, Olfaction and Endoscopic Sinus Surgery

Abstract

We assessed prospectively changes in olfaction and ciliary beat frequency (CBF) after functional endoscopic sinus surgery (FESS) in 70 patients with chronic sinusitis. CBF was measured by the microscopic-photometry technique 2, 4 and 6 months after FESS. Olfaction was evaluated by the Erlangener Smell Identification Test. Preoperative CBF was markedly reduced due to the infectious process. CBF was significantly improved ($p < 0.001$), reaching normal values 6 months postoperatively despite the endoscopic examination revealing normal nasal mucosa at around 3 months. The pattern of improvement of CBF was linear being more rapid between months 4 and 6. After operation olfactory-impaired patients were improved subjectively and objectively ($p < 0.001$ and $p = 0.003$). We conclude that impaired olfactory ability and CBF are significantly improved after FESS, and FESS demands longer postoperative follow-up periods for at least 6 months even if the clinical evaluations were normal.

Key Words

Functional endoscopic sinus surgery
Ciliary beat frequency

Introduction

Today, functional endoscopic sinus surgery (FESS) is a well-established operative procedure that has yielded excellent postoperative results, at least in the hands of experienced surgeons [1, 2]. Mucociliary function was found to be impaired in chronic sinusitis due to altered ciliary function [5], and optimized by operations to increase ventilation [6]. Improvement of olfaction and mucociliary transport have been shown by few authors following endoscopic sinus surgery [3–5]. Moreover, only one study has shown a postoperative improvement of ciliary beat frequency (CBF) 3 months after FESS [4].

The aim of this study is to evaluate the changes in olfaction and CBF over time after FESS by repeated CBF measurements.

Materials and Methods

Seventy patients presented with persistent symptoms and signs of chronic sinusitis with CT evidence were analyzed. All patients were candidates of FESS. The patients were staged using the OMU CT scan reported by May et al. [6] in 1990. The FESS procedure ranged from infundibulotomy to total sphenoethmoidectomy depending upon the stage of the disease. All subjects failed appropriate conservative medication that included intranasal steroids, antibiotics and antihistaminics. Patients with a history of previous nasal surgery, bronchial asthma, aspirin sensitivity or cystic fibrosis were excluded. We also excluded patients with extensive nasal polyposis blocking the olfactory area. Patients with nasal allergy were also excluded by allergy protocol including history, skin prick test and serologic test (total IgE, specific IgE). Hematology tests were also done to exclude relevant systemic disease and immune deficiency. All patients were subjected to a questionnaire and rigid endoscopy of the nasal cavity preoperatively and 2, 4 and 6 months postoperatively.

Mucociliary function was assessed by measurement of CBF. The nasal sample was taken by forceps biopsy from the medial surface of the middle turbinate. The sample was then placed in DMEM/Ham's F-12 (1:1) medium supplemented with *L*-glutamine 10% NU-serum, retinoid acid (10^{-7} *M*), penicillin (50 IU/ml) and streptomycin (50 μg/ml). The biopsy specimen was then placed on a standard

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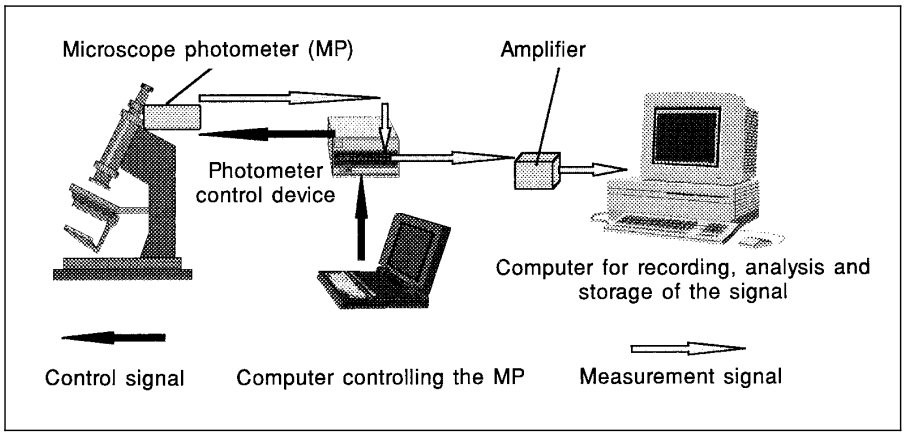

Fig. 1. Schematic representation of the CBF measuring device.

object glass and examined at room temperature within 3 h after taking the biopsy. The measurements were done using the microphotometry technique employing a Leitz DMR microscope to which a Leitz MPV SP compact microscope photometer is connected (fig. 1). At 500 × magnification, the diaphragm was chosen to record a 5-µm diameter round spot size that is positioned in the long axis of the cilia so that it is interrupted by ciliary beating. The changes in light intensity are transformed into electric signals that are then converted to a reading in hertz or beat cycle by a Compaq Prolinea 4/33S computer with a recording, storage and analysis system (Data Processing-AT Codas). A Fast Fourier Transformation was applied over each measurement so that the CBF was determined from the first harmonic. For each measurement, cells at ten different sites of each sample were recorded for 1min. CBF measurements were done for each nasal side of every patient preoperatively and 2, 4 and 6 months postoperatively, so that 560 measurements of CBF were performed.

Subjective evaluation of olfactory function was done by scoring the patients' symptoms as to be 0 = no complaint, 1 = mild olfactory impairment, 2 = moderate olfactory impairment, 3 = severe olfactory impairment, 4 = no smell at all. Objective assessment was done by using the Erlangener Smell Identification Test [7]. Eight items were presented to the patients, seven as test substances and one as a control, in the form of pen-like kits. Each nostril was examined separately, while closing the other, in addition to the bilateral assessment. Each pen was applied for not more than 4 s at a distance of about 4 cm from the nose. After that, the patient was asked to choose between four possible odors presented to him in a list. The olfactory test score sheet is from 0 to 8. A score of 6 or more is considered normal, <6 is a hyposmic score, and < 2 is the anosmic score. Subjective and objective evaluations were done preoperatively and 6 months postoperatively.

Results

We have studied 70 cases (44 males (62.9%) and 26 females (37.1%)), their age ranged from 8 to 66 years (mean 32.4, SD 15.12). The operative procedures were 140 in 70 patients (38 bilateral infundibulotomies (76 procedures), 26 bilateral infundibulotomies and anterior ethmoidectomies (52 procedures), and 6 bilateral total sphenoethmoidectomies (12 procedures)). Using the (OMU) CT grading system, after May 1990, 64 patients had bilateral grade 1–2 (mild disease), while 6 patients had bilateral grade 4 (pansinusitis). Follow-up clinically and for CBF was done over 2, 4 and 6 months postoperatively so that 560 measurements for CBF were performed, provided that the surgical cavities had satisfactorily healed which was usually around 3 months [4]. No major complications were found in the studied patients. Minor complications in the form of mild synechia or granulation tissue were found postoperatively and dealt with accordingly, so that 6 months postoperatively no complications were found.

CBF Preoperatively

CBF was found to be markedly reduced preoperatively. In the left side, the range was 4–11 Hz (mean 6.45) and in the right side it was 4–11 Hz (mean 7.49 Hz) (fig. 2a, b).

CBF Postoperatively

The CBF of both sides of the nose showed significant improvement postoperatively (table 1). In the left side of the nose, CBF were improved in 66 patients (94.2%), the same in 4 patients (2.9%) where total sphenoethmoidectomies were performed and postoperative synechia and granulation tissue was encountered ($p < 0.001$). In the right side, CBF were improved in 70 patients (100%) ($p < 0.001$) (fig. 2a, b).

Pattern of Improvement of CBF Over Time

The improvement of CBF shows a linear pattern reaching the normal values after 6 months with the greatest improvement between months 4 and 6 (fig. 2a, b), despite

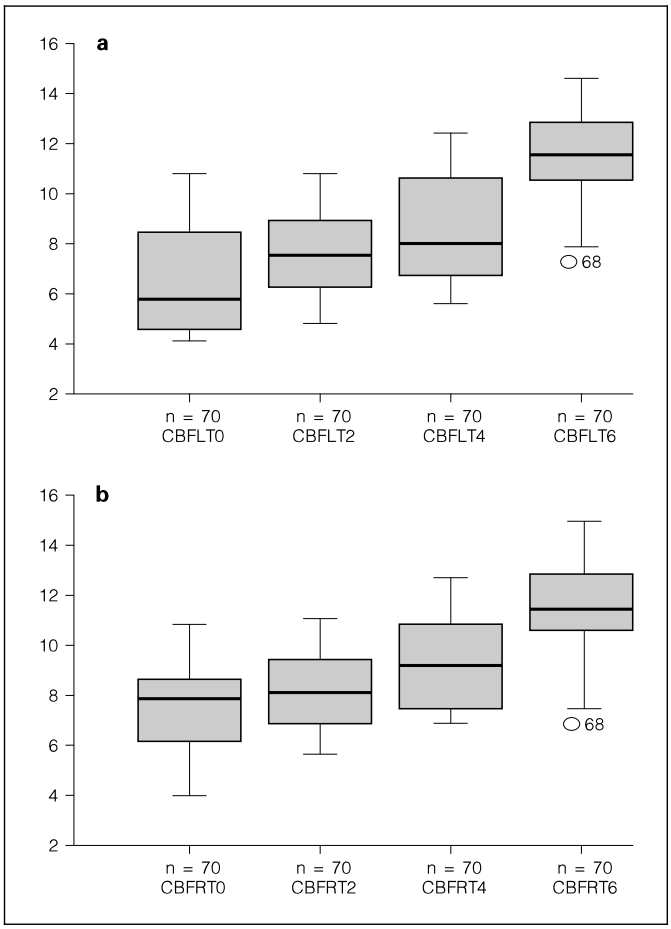

Fig. 2. Pattern of improvement of CBF on right (**a**) and left (**b**) sides. **a** CBFLT 0 = CBF left side preoperatively; CBFLT 2 = CBF left side 2 months postoperatively; CBFLT 4 = CBF left side 4 months postoperatively; CBFLT 6 = CBF left side 6 months postoperatively. **b** CBFRT 0 = CBF right side preoperatively; CBFRT 2 = CBF right side 2 months postoperatively; CBFRT 4 = CBF right side 4 months postoperatively; CBFRT 6 = CBF right side 6 months postoperatively.

that the postoperative endoscopic examinations demonstrated normal mucosa at around 3 months. There is no statistically significant difference between the right and left sides regarding the pattern of improvement. The analysis of variance for repeated measurement revealed that the time factor is highly significant ($p < 0.001$).

Changes in the Subjective Olfactory Scores

Considering patients with abnormal olfactory test scores, they represent a subgroup of 19 patients. The subjective olfactory scores were normal in 51 patients (72.9%) and mild to moderate olfactory impairment in 19 patients (27.1%). No patient complained of loss of smell. Preoperatively, the subjective scores in the impaired subgroup ranged from 1 to 2 (mean 0.9 ± 1.1). Postoperatively, they ranged from 0 to 1 (mean 0.32 ± 0.11). The subjective olfactory scores showed a significant improvement of olfactory ability ($p < 0.01$) (table 1).

Changes of the Objective Olfaction Test Scores

The olfaction test scores ranged from 3 to 5 preoperatively (mean 3.89 ± 0.88). No patient had an anosmic score. Postoperatively, the olfaction test scores in those patients ranged from 6 to 7 (mean 6.32) with a statistically significant increase of the scores to the normal level ($p < 0.02$) (table 2).

Discussion

Kennedy [8] stated that the purpose of FESS is to reestablish ventilation and mucociliary clearance of the sinuses. A large series has been published describing the technique, reporting subjective clinical benefit [1, 2, 8–11] and have consistently shown a clinical improvement estimated among 80–98%, but objective tests have not been performed.

Although some authors have found no cytological evidence of reduced ciliary activity in cases with chronic sinusitis [12], others recognized inhibition of ciliary activity parallel with increasing metaplasia [13]. Our results showed that the CBF is markedly reduced preoperatively which could be attributed to the effect of bacterial toxins on the cilia or the mucosal changes occurring with the infectious process as observed with the endoscopic examination.

Lund and Scadding [4] reported significant improvement of ciliary beat frequency after FESS and suggested that this improvement might be evidence of restoration of normal nasal physiology. Our results support the previous conclusions as we have measured CBF 2, 4 and 6 months postoperatively and showed a linear pattern of improvement that can be interpreted as decreased inflammation and restored nasal physiology. So, the repeated measurement of CBF postoperatively may be interpreted as an indirect indication of reduced inflammation/infection within the nasal cavity as a whole. Endoscopically, the nasal mucosa appears completely normal after variable periods at around 3 months. However, normal means of CBF were obtained 6 months postoperatively in both sides of the nose, i.e. 11.45 Hz in the left side and 11.56 Hz in the right side. The normal means was comparable to our normative data and those of Jorissen and

Table 1. CBF (Hz) pre- and post-FESS

CBF	Preoperatively		Postoperatively 6 months		p value
	mean	SD	mean	SD	
Left side	6.45	2.12	11.45	1.79	$p < 0.001$
Right side	7.5	1.86	11.56	1.71	$p < 0.001$

Table 2. Subjective and objective olfactory scores

Olfactory score	Preoperatively		Postoperatively 6 months		p value
	mean	SD	mean	SD	
Subjective	0.9	1.1	0.1	0.32	$p < 0.01$
Objective	3.89	0.88	6.32	0.76	$p < 0.02$

Bessems [14] . Moreover, the most rapid improvement in CBF was measured between months 4 and 6 postoperatively from which we can conclude that nasal physiology may need longer to normalize despite the normal endoscopic appearance. The benefit of longer follow-up duration even if clinical examination revealed normal findings is more supported by these results.

Our results showed a significant improvement of olfaction ability in the olfactory-impaired patients after FESS either subjectively ($p < 0.01$) or objectively ($p < 0.02$) when follow-up is considered for 6 months. Our results were in agreement with those reported by Hosemann et al. [15], Yamagishi et al. [16] and Yang-Gi et al. [5]. On the other hand, the results did not correspond to those of Lund and Scadding [4], who reported that olfaction showed no overall improvement in the objective test despite a significant subjective improvement. The controversy could be due to the fact that we consider cases of abnormal olfactory test scores while they consider the whole cases. No patients showed deterioration of olfaction postoperatively, either subjectively or objectively. The results support the suggestion that increased ventilation and drainage of secretion following FESS may improve the olfactory ability and CBF and in turn the mucociliary transportation.

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