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The effect of endoscopic sinus surgery on mucociliary activity and healing of maxillary sinus mucosa

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SUMMARY

The aim of this study was to determine histologic findings in the maxilaarysinus mucosa by scanning electron microscopy (SEM) and transsmission electron microscopy (TEM), and ciliary activity within the nasal cavity by measuring the speed of mucociliary transport and after endoscopic sinus surgery (ESS).

Thirty patients were enrolled. Thirtyeight antral mucosae of 24 24 patients were investigated according to ultrastructural changes and 6 patients were accepted as controls. At the 12th week, 12 antral nasal mucosae specimens of 8 patients were evaluated. All the specimens were taken from the medial rear wall of the antrum. The specimens were observed under a SEM and TEM. The mucociliary activity was measured within the nasal cavity by a saccharin test in all patients before the operation and after 12 weeks. Twenty people served as controls. In the specimens of the preoperative mucosa, the ciliated epithelium was heavily deciliated, interdigitation of the cell was loosened. In the samples taken 12 weeks after the operation, the ciliated cells were irregularly seen, the number of goblet cells was about the same as in the preoperative group and in the control, the number of the gland openings was higher than in the preoperative group and in the control. Also the interdigitation of the cells was enhanced. The histological and morphological features of the mucosa had improved. The period of the preoperative saccharin test was 12.15 minutes, whereas the period of the postoperative test was 9.08 minutes. The improvement was significant but both results were also significantly longer compared to the controls.

These obervations suggest that the histological, morphological and mucocilliary activity of the mucosa have not yet improved completely, it takes more than 12 weeks to recover, and the patients should be closely monitored in the postoperative months.

Key words: endoscopic sinus surgery, mucociliary activity, scanning and transmission electron microscopy, healing, follow-up

INTRODUCTION

In the pathologic states of the maxillary sinu, the ultrastructural elements of the mucos change and the mucociliary activity deteriorates. The ciliated cells, goblet cells and submucosal glands are necessary for normal mucociliary function. In various studies, the number of these ultrastructural elements under pathologic conditions were investigated (Tos et al., 1984; Myging et al., 1974).

Endoscopic sinus surgery plays a major role in the management of paranasal sinus diseases. Much interest recently has been generated concerning histologic and functional aspects of the regenerated sinus mucosa after endoscopic surgery. There is a limited number of studies about this topic after ESS (Fang, 1994).

The aim of this study was to observe histopathologic and ultrastructural ciliary changes by SEM and TEM in the mucosa-of the regenerating sinus and to evaluate mucociliary activity within the nasal cavity at the same time after ESS.

MATERIALS AND METHODS

The 38 specimens were taken from 24 patients, ranging in age between 14 and 57 years old, 10 woman and 14 men, undergoing the ESS procedure. Six antral mucosae of patients who had received septoplasty were used. The control group existed from patients proven to be without evidence of sinusitis by rhinoscopy and radiology. Chronic paranasal sinusitis includes classic symptoms and signs such as mucopurulent nasal drip,

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nasal obstruction, polyppoid changes of middle turbinates, nasal polyps, not responding to antibiotic therapy for 2 months, and after the surgery, the CT still revealing evidence of sinusitis. All the patients were investigated by coronal and axial CT preoperatively. ESS was performed under local and general anesthesia. The ostium of the maxillary sinus widenend and specimens were taken from the medial rear wall of the antrum by cup forceps through the dilated ostium during the operation and postoperative follw-up. Twelve antral mucosae from 8 patients were removed at the 12th week. The specimens were fixed in 3% glutaraldehyde at 4°C for 2 hours, and then managed with postfixation in 1% ostium tetroxide, dehydration in a alcohol series, and critical point drying. After coating with gold by sputtering, the surface of the specimens was analyzed under a Jeol JSM 5200 (Japan) scanning electron microscope. For transmission electron microscopy, the specimens after managing with toluol, were embedded in epon 812. One-micrometer sections were cut and stained with toluidine glue. Cuts of 400-600 nm were prepared, stained with uranyl acetate and lead citrate, and examined by a Jeol 1200 EX II (Japan) transmission electron microscope.

The ciliated cells, deciliated cells, goblet cells, and submucosal gland openings were counted in randomly chosen 5 visual fields by SEM (×1000) and the average of the counts of 5 visual fields were taken for each specimen. Both groups were seperately evaluated and the histological results were based on all patients. Before the operation and after 12 weeks, each patients' mucociliary activity was measured by a saccharin test. While the patient was in a sitting position, a saccharin particle was placed on the nasal septum opposite of the anterior-inferior tip of the middle nasal turbinate, and the period until a sweet taste was experienced, was determined. The saccharin times of 20 normal people were taken as controls.

Student's *t*-test and a 95% confidence interval were used to compare each group.

RESULTS

Scanning electron microscopy in the control group.

The mucosal epithelium was essentially covered by abundant ciliated cells and equally dispersed with goblet cells and submucosal gland openings. In 5 randomly chosen fields, there was a mean of 3.4 goblet cells and 4.2 submucosal gland openings (Table1). The intracellular construction was tight and no pathology was seen on the surface (Figure 1).

Table 1. Histologic structures in the groups.

	Globet cells	ciliated cells	nonciliated cells	submucosal gland openings
Preoperative	3.1±0.77 (2.48-3.62)	-	69.71±22 (49-90)	6.37±2.06 (4.64-8.10)
Postoperative	3.8±0.80 (3.11-4.48)	14.5±1.29 (13.44-15.52)- full covered	48.2±8.80 (41-54)	8.60±1.14 (7.68-9.05)
Control	3.4±0.82 (2.75-4.16)		-	4.2±1.1 (3.31-5.18)

Figure 1. Scanning electron micrograph of normal antral mucosa. Goblet cells (G), gland openings (GO). Note intact ciliae with regular contours of the surface.

Transmission electron microscopy in the control group

The maxillary antrum was covered by pseudostratified ciliated epithelium (Figure 2). There were ciliae and microvilli on the apical ends of the cells. The shape of the cilia was normal and had its "9+2" microtubule pattern in axial sections. There were goblet cells scattered among the ciliated cells. The nuclei of the ciliated cells were pushed downwards and numurous vesicles filled with mucin located toward the surface were observed. There were also sphericaland poligonal cells at the base.

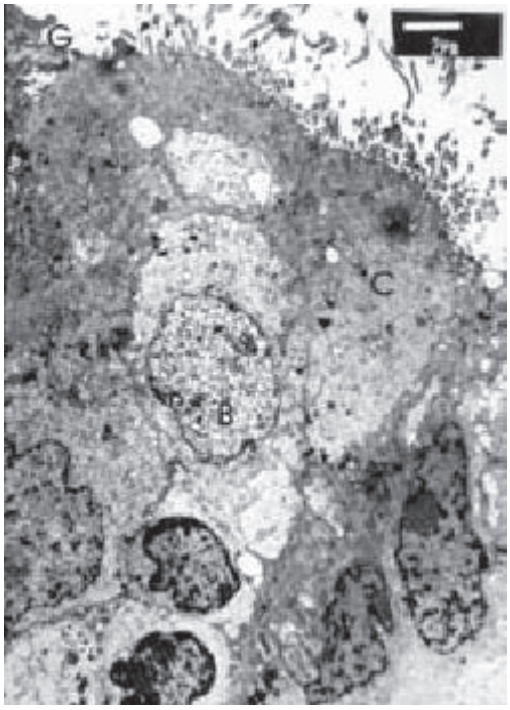

Figure 2. Transmission electron micrograph of normal antral mucosa. Goblet cells (G), Basal cells (B), Columnar cells (C).

Scanning electron microscopy in the preoperative sinusitis group

On the surface of all the samples, abundant purulent material, necrotic structures and fibroid mesh were observed (Figure 3). Epithelial cells were flattened and intracellular gaps occured. The ciliated cells were lost almost totally and some compound ciliae were seen. The deciliated epithelial cells constitute a

mean number of 69.7, whereas the mean number of goblet cells and submucosal sinus openings were 3.1 and 6.3, respectively. Compared with our control material, the sinusitis group showed similar changes in the number of goblet cells, but a significantly higher number in submucosal gland openings ($p<0.05$).

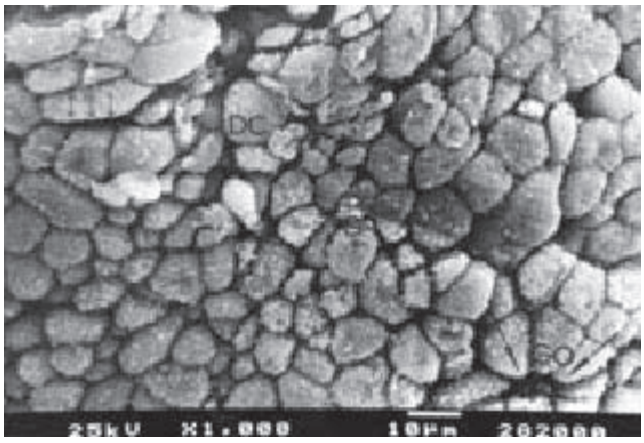

Figure 3. Scanning electron micrograph of preoperative mucosa with chronic maxillary sinusitis. Note numerous deciliated cells (DC) some gland openings (GO), Goblet cells (G), and detachment between the cells (arrow).

Transmission electron microscopy in the preoperative sinusitis group

The ciliae were blunted, compounded and sticked on the apical end. The interdigitation of the cells was loosened (Figure 4). The numbers of goblet cells and basal cells were similar compared to the controls.

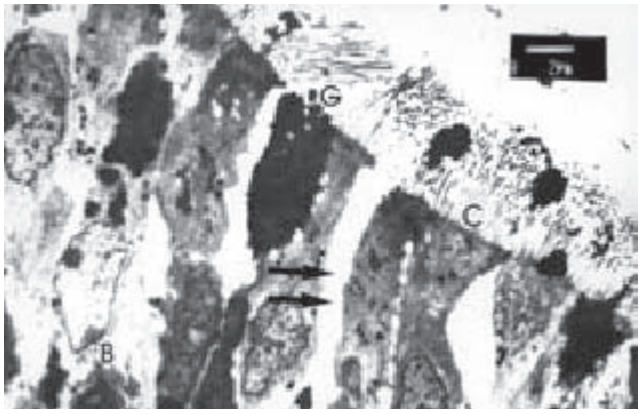

Figure 4. Transmission electron micrograph of preoperative antral mucosa. The interdigitation of the cells was loosened (arrows), Goblet cells (G), Basal cells (B), and Columnar cells (C).

Scanning electron microscopy in the postoperative (12th week) group

There was no purulent material, and no necrotic and fibroid mesh on the samples (Figure 5). The ciliated cells were scattered in microvilli and deciliated cells, mean number of 14.5, compared with the preoperative groups with no ciliated cells. The deciliated cells were counted as a mean of 48.2. The increase of ciliated epithelium was significant ($P<0.001$). There was no significant change in the number of goblet cells, 3.8 ($p>0.05$). There was a significant increase in the submucosal gland openings, mean of 8.6 when compared with the control and preoperative groups ($p<0.05$).

Figure 5. Scanning electron micrograph of postoperative mucosa. Note the difference between preoperative mucosa and postoperative mucosa. Gross recovery has occured. Ciliated cells (C) can be seen between deciliated ones. Note the irregular mucosal surface, some goblet cells (G) protruding, some gland openings (GO), microvilli cells (MC) and the gap between the cells.

Transmission electron microscopy in the postoperative group

There was single layered flat or cubic epithelium instead of ciliated epithelium (Figure 6). The microvilli were seen especially on the flat cells and some ciliae on the cubic cells. The had the conventional "9+2" microtubule pattern. The number of goblet cells was somewhat decreased and the density of mucin granules in these goblet cells were observed immature. Some nuclei of basal cells had two nuleoli. The interdigitation of the cells had recovered.

Figure 6. Transmission electron micrograph of postoperative antral mucosa. Note single layered ciliated cubic epithelium (C), Goblet cells (G), and Basal cells (B). The microvilli (MC) are especially seen on the flat cells. The interdigitation of the cells had recoverd (arrows).

Saccharin tests

The results of the saccharin test were between 7 and 25 minutes in the preoperative group with a mean of 12.15 minutes (Table

2). The postoperative saccharin tests revealed times between 6 and 15 minutes with an average of 9.08 minutes. The average of the control group was 6.42 minutes. The improvement in the postoperative group compared with the preoperative one was significant ($p<0.01$). Somehow, the results of both the preoperative and postoperative groups compared with the control group were significantly longer ($p<0.01$).

Table 2. The results of saccharin test in the groups.

	saccharin test (minute)
Preoperative	12.15±6.22 (8.19-16.10)
Postoperative	9.08±3.07 (7.38-11.18)
Control	7.31±1.31 (6.08-8.15)

DISCUSSION

A normal functioning paranasal sinus depends on coordinated ciliary activity, glandular secretion and characteristic features of the mucosa. Andersen et al. (1974) have measured mucociliary activity by the saccharin test which use is simple and accurate. We wanted to show a change in the mucociliary transport in the nasal cavity because chronic infection within the paranasal sinuses might effect the nasal mucosa. Besides using the saccharin test, our preoperative and postoperative test results revealed that the duration was still longer compared to the controls and that mucociliary activity had not returned to normal levels after 12 weeks, although a gross recovery was apperent. Similarly, Behrbohm and Sydow's results (1991) about the mucociliary clearance of the antral mucosa before endoscopic sinus surgery and after 6-18 months follow-up, using 99mTc-SC in 34 sinuses of 22 patients, showed that only 56% of the sinuses was within the normal range. No recovery of the mucociliary function in 11 sinuses of 7 patients with impaired healing was observed. In another study reagrding postoperative recovery of functioning mucosa, Min et el. (1994) removed completely one side of the sinus mucosa of rabbits and used the contralateral side as their control. They studied mucociliary transport and transmission electron microscopy of the mucosae at 6, 8, 10 and 12 weeks, respectively. They found that the mucociliary activity was reduced (6.4 mm/min), compared to the control side (10.8 mm/min). The percentage of beating cilia went up from 16% to 66%, and 88% of the regenerated mucosa was a combined pseudostratified ciliated columnar epithelium. Controversies still exist in various reports regarding postoperative recovery of functioning mucosa. Frosgren et al (1993) reported that a rapid regeneration of the epithelium within 2 weeks took place in the maxillary sinus of rabbits after an experimental operative removal of the mucosa. However, regeneration of the lamina propria was incomplete and the submucosal glands had not been regenerated even 9 months later. According to Benninger et al. (1989) only 20% to 53% of the sinuses were regenerated with normal ciliated columnar epithelia. Kennedy and Shaalan (1989) also reported on impaired mucociliary clearance of the maxillary sinus in rabbits subjected to radical mucosal removal. These results display less mucus production with decreased seromucinous glands and alteration in the mucociliary transport mechanism.

In another study, 15 antral mucosae with sinusitis after endoscopic sinus surgery were investigated in the16th week. A significant decrease in number of goblet cells and an increase of submucosal glands were observed in the sinusitis group, but in the postoperative group the number of goblet cells remained the same and the number of submocusal gland openings was higher when compared to the controls (Fang, 1994). The present study showed that although there was a slight, but not significant, decrease in the number of goblet cells in the sinusitis groups, the submucosal gland openings of the postoperative groups were significantly higher than in the sinusitis and control groups. The ciliated epithelium also recovered in a irregular way. These irregular epithelial surfaces and abundant submucosal gland openings may result in an abnormal mucous blanket and improper mucociliairy activity which comprise the defense mechanism and cause mucosal infections (Engquist et al., 1984).

It is concluded that a full functional and histologic recovery of the maxillary sinus mucosa after EES requires more than 3 months. It is evident that a close follow-up is necessary to preclude reinfections of the unstable mucosa during healing. Further studies about the total recovery of the sinuses are mandatory to assess the efficacy of EES.

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