

THE JOURNAL OF Allergy AND Clinical Immunology

January 1997 • Volume 99 • Number 1

Restoration of the mucociliary clearance of the maxillary sinus after endoscopic sinus surgery

Katsuhisa IkedaMD^a [[MEDLINE LOOKUP](#)]

Takeshi OshimaMD^a [[MEDLINE LOOKUP](#)]

Masayuki FurukawaMD^a [[MEDLINE LOOKUP](#)]

Yukio KatoriMD^a [[MEDLINE LOOKUP](#)]

Akira ShimomuraMD^a [[MEDLINE LOOKUP](#)]

Tomonori TakasakaMD^a [[MEDLINE LOOKUP](#)]

Shin MaruokaMD^b [[MEDLINE LOOKUP](#)]

- *Sendai, Japan*

- [Previous article](#) in Issue
- [Next article](#) in Issue
- [Drug links](#) from Mosby's DrugConsult
- [Genetic information](#) from OMIM
- Citation of this Article
 - View on [PubMed](#)
 - Download in [citation manager format](#)
 - Download in [Medlars format](#)
- [Related articles](#) in PubMed

Sections

- [Abstract](#)
- [Methods](#)
- [Results](#)
- [Discussion](#)
- [References](#)
- [Publishing and Reprint Information](#)

Background: Whether endoscopic sinus surgery (ESS) restores the mucociliary clearance of the maxillary sinus needs further evaluation.

Methods: We evaluated the mucociliary clearance of the maxillary sinus by using a radionuclide technique in 12 patients with chronic sinusitis (sinusitis group) and in six patients who had undergone ESS 6 to 14 months after the surgery (post-ESS group). The mucosal cilia taken from the maxillary sinus in 12 patients with sinusitis before and after ESS (paired experiments) were examined by light and electron microscopy.

Results: The radionuclide placed endoscopically in the maxillary sinus in eight patients immediately after ESS maintained $81.2\% \pm 16.3\%$ of its radioactivity after 30 minutes. This result was consistent with results in four patients with untreated chronic sinusitis in whom the radionuclide had been instilled by antral puncture ($86.9\% \pm 3.5\%$). On the other hand, in six patients in the post-ESS group the radionuclide maintained only $25.9\% \pm 11.6\%$ of its radioactivity, demonstrating statistically significant differences from those of both the sinusitis group without ESS ($p < 0.005$) and the group 4 days after ESS ($p < 0.005$). The absence of the cilia in the sinusitis condition was recognized in $35.5\% \pm 12.1\%$ ($n = 12$) of the epithelial cells. On the other hand, the absence of cilia was significantly ($p < 0.01$) reduced to $5.3\% \pm 3.7\%$ of the epithelial cells in the post-ESS condition. Electron microscopic observation also revealed abnormal cilia in the sinusitis condition, whereas the mucosal cilia were regularly arranged in the post-ESS condition.

Conclusions: The mucociliary clearance of the maxillary sinus disturbed by chronic inflammation was restored by ESS, indicating the clinical effectiveness of ESS for the treatment of chronic sinusitis. (J Allergy Clin Immunol 1997;99:48-52.)

ESS Endoscopic sinus surgery

(Click on a term to search this journal for other articles containing that term.)

Key Words: [Endoscopic sinus surgery](#), [mucociliary clearance](#), [chronic sinusitis](#), [radionuclide](#), [cilia](#), [maxillary sinus](#)

Endoscopic sinus surgery (ESS) is a newly developed but established surgical procedure for the treatment of maxillary and frontal sinus diseases. The basic purposes of ESS are to remove the diseased ostiomeatal complex including the anterior ethmoid sinus and to reestablish ventilation and drainage of the dependent larger sinuses. During recent years, it has been recognized that irreversible diseases are rarely present and that diseases in secondarily involved sinuses are usually reversible when proper ventilation is reestablished.^{1,2} ESS has an advantage over other approaches because it saves the patient from an external skin incision and injury to the intervening bone. The final goal of ESS for the treatment of inflammatory mucosal disease does require the restoration of normal mucociliary function, leading to improvement of mucosal pathologic conditions and therapeutic effectiveness. Although several studies^{1,4} have reported on the pathophysiologic aspects after ESS, no objective evaluation has been presented regarding the changes in mucociliary clearance and structure of the mucosal lining produced by ESS. Restoration of mucociliary clearance and the regeneration of ciliated cells of the maxillary sinuses are essential to the success of ESS.

Included in this study were 20 men and 10 women, ranging in age from 12 to 71 years (mean age, 45.5 ± 15.8 years). Chronic sinusitis was diagnosed according to the definition proposed by Shapiro and Rachelefsky,⁵ including the presence of two major criteria or one major criterion and two minor criteria of signs and symptoms for more than 3 months with thickening of the mucosa and/or opacification of sinus revealed by coronal computed tomographic scan. ESS was performed after local or general anesthesia was induced by the techniques described, respectively, by Kennedy et al.¹ and Stammberger.² The patient was placed in the supine position with the head slightly elevated and turned slightly toward the surgeon. For topical anesthesia, 4% lidocaine was used. After local anesthesia was induced, we carefully injected 1% xylocaine with 1:100,000 epinephrine in to the surgical site and packed the nose with 1:5000 epinephrine-soaked cotton pads and gauze. An infundibulotomy was then performed, whereby the medial infundibular wall was peritomized with a sickle knife. The uncinate process was then subluxated medially and removed with forceps. The anterior ethmoid cells and ethmoid bulla were also removed with forceps. The posterior ethmoid and sphenoid sinuses could be evacuated step by step, if necessary. Finally, the maxillary ostium was identified visually by a 30-degree or 70-degree endoscope. The obstructed opening in severe cases was widened to the anterior and posterior fontanelles with a curette and back-biting forceps. All antral mucosa of the chronic maxillary sinus was left intact.

Twelve patients with chronic sinusitis (sinusitis group) were randomly selected for the mucociliary clearance test. To measure the mucociliary clearance of the maxillary mucosa, technetium 99m–labeled Tc-human serum albumin was dissolved in physiologic saline solution to adjust ~ 37 MBq/ml μ Ci of radioactivity. A droplet of 5 μ l of ^{99m}Tc -human serum albumin was placed on the bottom of the maxillary sinus through the enlarged natural orifice under endoscopic control after complete removal of the sinus effusion in eight patients 4 days after ESS in the sinusitis group. To further confirm the preoperative mucociliary function of the maxillary sinus in chronic inflammatory conditions, the radionuclide was placed in the bottom of the maxillary sinus during therapeutic puncture in four patients with chronic sinusitis. Antral puncture was performed after local anesthesia was induced with lidocaine on the nasal cavity for 10 minutes. The maxillary antrum was then punctured, aspiration was attempted, and the radionuclide was instilled. Six patients at 6 to 14 months after ESS (post-ESS group), who were not included in the sinusitis group, were judged as completely improved on the basis of sinus-related symptoms, nasal endoscopic findings, and coronal computed tomographic scan and were selected for the mucociliary clearance study. In the post-ESS group the radionuclide was introduced into the maxillary sinus through the maxillary ostia. The patient was immediately seated in a chair with the front of the head in a gamma camera (ZLC, Siemens, Hoffman Estates, Ill.). The head was fixed in a stand with adhesive tape throughout the measurement. The radioactivity was measured at 1-minute intervals, and each datum was stocked in a computer for later analysis. Each datum was retrieved and displayed in a color cinematograph on a television screen. Three markers were placed on the side of the head, 5 cm apart from each other, to calibrate the magnified camera image and to monitor the immobility of the patient. In order to measure the radioactivity, the region of interest was selected in the maxillary sinus containing the ^{99m}Tc -human serum albumin. Time- activity or clearance curves were drawn by the computer for a region of interest after correcting the physical half-life of ^{99m}Tc (6.02 hours). The radioactivity during 0 to 1 minute at the beginning of measurement was defined as 100%, and each 1-minute interval was subsequently expressed as the percentage.

In 12 patients, mucosal biopsy specimens were taken from the posterior wall of the antrum by cup forceps through the enlarged natural orifice. These patients also underwent another biopsy of the antral mucosa after the gross appearance of the antrum was judged as recovered by endoscopic nasal evaluation, performed in the doctor's office 6 to 14 months after ESS. For light microscopic study, the specimens were fixed in 4% paraformaldehyde buffered to pH 7.4 with 0.1 mol/L phosphate buffer for 60 minutes at 20° C and rinsed twice with 0.2 mol/L phosphate buffer. Then the tissue blocks were postfixed in 1% OsO₄ with 0.1 mol/L phosphate buffer, pH 7.4, for 60 minutes at 4° C, dehydrated in graded ethanol, and embedded in Epon 812 (TAAB Laboratories, Berkshire, England). The embedded samples were cut with a microtome, stained with toluidine blue, and examined by a light microscope. Special attention was paid to the absence or presence of the cilia in the epithelial cell. At least 100 cells were counted, and the number of epithelial cells with the cilia missing was expressed as the percentage of the total number of epithelial cells. For scanning electron microscopy, the specimens were immediately immersed in cold 2.5% glutaraldehyde in 0.1 mol/L phosphate buffer, rinsed in buffer, postfixed in 1% OsO₄, dehydrated with alcohol, and dried at critical point. After coating with platinum by sputtering, the surface of the specimen was analyzed under a scanning electron microscope (S-5000S; Hitachi, Tokyo, Japan) operated at 3 kV.

Informed consent was obtained from all patients, and the study was approved by the Ethical Committee of Tohoku University School of Medicine.

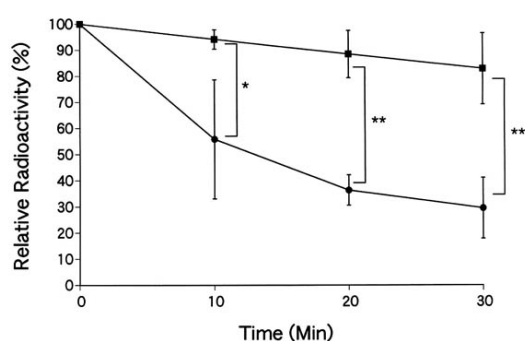
The data are given as means $\pm$ SD, with *n* indicating the number of observations in different patients. Statistical significance of the data was analyzed by Student's *t* test or a paired two-tailed *t* test, and *p* values less than 0.05 were accepted as significant.

Results

TOP

We examined the mucociliary clearance of both the inflamed maxillary sinus mucosa in eight patients 4 days after ESS and in four patients who had not undergone ESS and the clearance of the healed mucosa in six patients 6 to 14 months after ESS. At 10-minute intervals, the percentage of the radioactivity of the region of interest in the maxillary sinus in each group was averaged (Fig. 1).

Fig. 1. Time course of residual rate of radioactivity in maxillary sinus. *Squares*, Sinusitis groups; *circles*, post-ESS groups. **p* < 0.05, ***p* < 0.01.

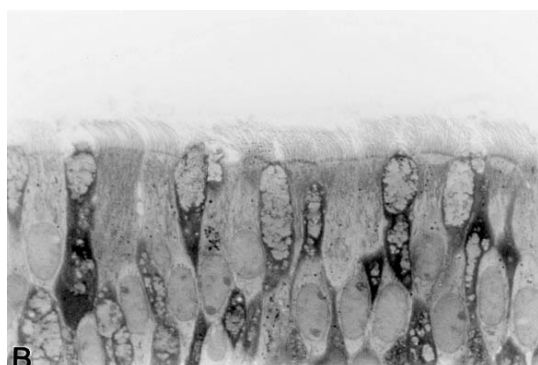
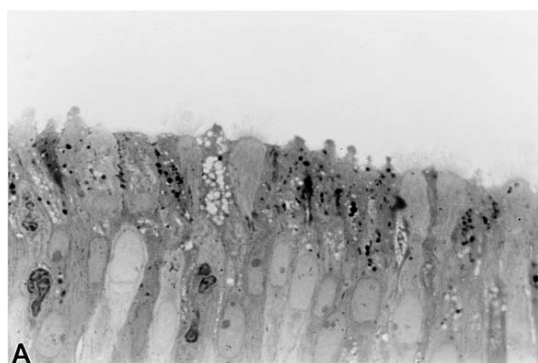


[Click on Image to view full size](#)

In the sinusitis group the radioactivity in eight patients 4 days after ESS gradually but significantly decreased to $81.2\% \pm 16.3\%$ ($n = 8$) of the initial value after 30 minutes. This result was consistent with that of four patients in whom radionuclide had been instilled by antral puncture ($86.9\% \pm 3.5\%$), indicating that the maxillary antrostomy with intact maxillary sinus mucosa by ESS does not disturb the mucociliary clearance of the maxillary sinus mucosa for at least 4 days after surgery. On the other hand, rapid clearance of radioactivity was observed in the post-ESS group 10 minutes after instillation of the radionuclide. The radioactivity after 30 minutes decreased to $25.9\% \pm 11.6\%$ ($n = 6$), which was significantly lower, according to Student's *t* test, than those of both sinusitis groups, that is, without ESS ($p < 0.005$) and 4 days after ESS ($p < 0.005$). These findings indicate that the mucociliary function of particle transportation was restored after ESS.

In the sinusitis condition, light microscopic examinations showed abnormalities of the cilia such as total loss, partial loss, or short height (Fig. 2, A).

Fig. 2. Light micrographs of mucous epithelium of maxillary sinus. **A**, Sinusitis conditions. (Original magnification $\times 1000$.) **B**, Post-ESS conditions. (Original magnification $\times 1000$.)

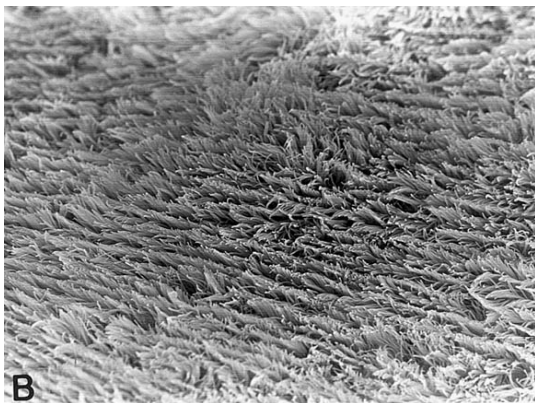
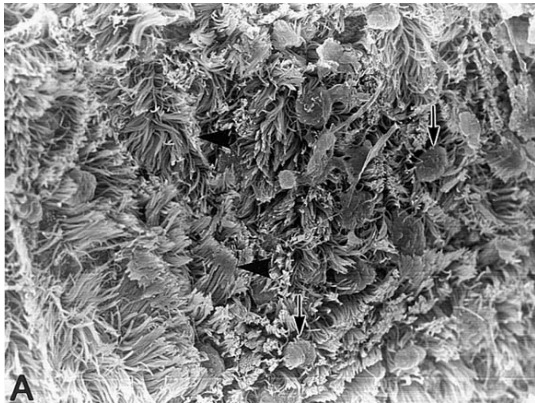


[Click on Image to view full size](#)

The mean absence of cilia was $35.5\% \pm 12.1\%$ ($n = 12$) of the epithelial cells. The ratio of the epithelial cells without cilia was significantly reduced in the post-ESS condition ($5.3\% \pm 3.7\%$, $p < 0.01$, paired *t* test, Fig. 2, B ■) as compared with that in the sinusitis condition. Electron microscopic observation revealed the presence of compound cilia, fusion of ciliary membrane, and irregular

arrangement (Fig. 3, A).

Fig. 3. Scanning electron micrographs of mucous epithelium of maxillary sinus. **A**, Sinusitis conditions. (Original magnification $\times 1500$.) *Arrows*, Compound cilia; *arrowheads*, fusion of ciliary membrane. **B**, Post-ESS conditions. (Original magnification $\times 1500$.)



Click on Image to view full size

In comparison, the cilia in the post-ESS condition seemed to be regularly arranged (Fig. 3, B¹⁰). Thus morphologic findings of the abnormal cilia of the maxillary mucosa may reflect the disruption of the mucociliary function.

Discussion

TOP

A variety of clinical studies have indicated that ESS is symptomatically effective in 76.0% to 87.5% of the patients who are followed up for 1 to 3 years.^{6 10} The reversible changes in the mucosal pathologic conditions are warranted by the concept of underlying pathogenesis and pathophysiology in the development of sinusitis. The final pathway can be explained by initial and secondary obstruction of the ostiomeatal complex, as well as by infection in the underlying sinusitis, although chronic sinusitis is brought about by multifactorial causes. Elimination of the diseased ostiomeatal complex may allow ventilation of secondarily involved sinuses and the recovery of

mucociliary function.^{1 4}

Messerklinger¹¹ examined the secretion transport in various sinuses in human cadavers. The mucus produced in the maxillary sinus is transported by the ciliary beat from the floor of the sinus in starlike routes along the walls of the sinus to the natural ostium. The diseased sinus results in the retention of secretions and poor ventilation. King¹² examined the excretion of contrast medium infused into the maxillary sinus and noted a decline of mucociliary transport in chronic sinusitis. Endoscopic observation on the clearing of retained secretions within the sinus suggests that mucociliary clearance is reestablished 4 weeks after ESS.¹³ Furthermore, dye applied to the maxillary sinus was proven to be transported into the nose through middle meatal antra.¹⁴ Unfortunately, these studies lack objective evaluation of mucociliary clearance in the maxillary sinus mucosa.

This study includes two procedures with which to evaluate the mucociliary function of the maxillary sinus in the inflamed condition. The surgery in the maxillary ostia may influence the mucociliary clearance caused by changes in pH and CO₂ in the mucous blanket,¹⁵ despite the absence of manipulation in the maxillary sinus mucosa. Because the findings obtained from the two procedures in which the radionuclide was introduced into the maxillary sinus were equivalent, the surgical manipulation in the maxillary ostia with the intact maxillary sinus mucosa is unlikely to influence the mucociliary clearance of the maxillary sinus. In contrast to the sinusitis condition, the healed mucosa of the post-ESS group significantly enhanced the mucociliary clearance in comparison with the groups with chronic sinusitis. Although evaluation of the radionuclide study in the same patients before and after ESS would have provided a better study design, it could not be permitted by our ethics committee because of excessive exposure to radiation. Nevertheless, this study directly demonstrates that the mucociliary function disturbed in the diseased mucosa of the maxillary sinus was actually restored by ESS.

The mucociliary function is determined by the ciliary activity, the volume and physical properties of mucus and periciliary fluid, and the efficiency of mucociliary interaction.¹⁵ The decrease in the frequency of ciliary beat was observed in the mucous membranes excised from the maxillary sinuses of patients with chronic sinusitis.¹⁶ Morphologic changes of the cilia were also found in chronic sinusitis,^{17 18} which was consistent with the results of this study. An abnormal mucous blanket and a tethering phenomenon in chronic sinusitis have also been observed.¹⁹ Therefore all three factors mentioned above are likely to be related to the reduction of the mucociliary clearance in the maxillary sinus. The underlying mechanisms for the recovered mucociliary function were supported by the increase of the ciliated epithelial cells and improvement in the arrangement of the cilia. A recent experiment, designed as a rabbit model of chronic sinusitis, indicated that the cilia abnormalities are grossly associated with abnormalities in sinus function and that natural osteotomy is generally effective in treating sinusitis.²⁰ Improvement of rheological properties and mucociliary interaction after ESS is expected on the basis of etiologic processes of the disturbance in mucociliary clearance, although there is no direct proof.

In conclusion, we demonstrated that ESS restored the mucociliary clearance disturbed by chronic

inflammation. The mucosal cilia in the maxillary sinus were recovered in post-ESS conditions. These findings support the clinical efficacy of ESS in the treatment of chronic sinusitis.

References

[TOP](#)

1. Kennedy DW, Zinreich SJ, Rosenbaum AE, Johns ME. Functional endoscopic sinus surgery: theory and diagnosis. *Arch Otolaryngol* 1985;111:576-82.

[MEDLINE](#)

2. Stammberger H. Endoscopic endonasal surgery: concepts in treatment of recurring rhinosinusitis. I. Anatomic and pathophysiological considerations. *Otolaryngol Head Neck Surg* 1986;94:143-7.

[MEDLINE](#)

3. Stammberger H. Functional endoscopic sinus surgery. Concept, indications and results of the Messerklinger technique. *Eur Arch Otorhinolaryngol* 1990;247:63-76.

[MEDLINE](#)

4. Lanza DC, Kennedy DW. Current concepts in the surgical management of chronic and recurrent acute sinusitis. *J Allergy Clin Immunol* 1992;90:505-11.

[MEDLINE](#)

5. Sharpiro GG, Rachelefsky GS. Introduction and definition of sinusitis. *J Allergy Clin Immunol* 1992;90:417-8.

6. Rice DH. Endoscopic sinus surgery: results at 2-year follow-up. *Otolaryngol Head Neck Surg* 1989;101:476-9.

[MEDLINE](#)

7. Levine HL. Functional endoscopic sinus surgery: evaluation, surgery, and follow-up of 250 patients. *Laryngoscope* 1990;100:79-84.

[MEDLINE](#)

8. Kennedy DW. Prognostic factors, outcomes, and staging in ethmoid sinus surgery. *Laryngoscope* 1992;102(suppl 57):1-18.

[MEDLINE](#)

9. Lund VJ, Holmstrom M, Scadding GK. Functional endoscopic sinus surgery in the management of chronic rhinosinusitis. An objective assessment. *J Otol Laryngol* 1991;105:832-5.

10. King JM, Caldarelli DD, Pigato JB. A review of revision functional endoscopic sinus surgery. *Laryngoscope* 1994;104:404-8.

[MEDLINE](#)

11. Messerklinger W. Über die Drainage der menschlichen Nasennebenhöhlen unter normalen und pathologischen Bedingungen. 1. Mitteilung. Monatsschr Ohrenheilkd Laryngol Rhinol 1966;101:56-68.

12. King E. A clinical study of the functioning of the maxillary sinus mucosa. Ann Otol 1935;44:480-2.

13. Kennedy DW, Zinreich SJ, Shaalan H, Kuhn F, Naclerio R, Loch E. Endoscopic middle meatal antrostomy: theory, technique, and patency. Laryngoscope 1987;97(suppl 43):1-9.

MEDLINE

14. Friedrich JP. Traitement par meatotomies endoscopiques des sinusites maxillaires chroniques. Med et Hyg 1984;41:3410-6.

15. Warnner A. Clinical aspects of mucociliary transport. Am Rev Respir Dis 1977;116:73-125.

MEDLINE

16. Ohashi Y, Nakai Y. Reduced ciliary action in chronic sinusitis. Acta Otolaryngol 1983;(suppl 397):3-9.

17. Takasaka T, Sato M, Onodera A. Atypical cilia of the human nasal mucosa. Ann Otol 1980;89:37-45.

18. Ohashi Y, Nakai Y. Functional and morphological pathology of chronic sinusitis mucous membrane. Acta Otolaryngol 1983;(suppl 397):11-48.

19. Majima Y, Sakakura Y, Matsubara T, Miyoshi Y. Possible mechanisms of reduction of nasal mucociliary clearance in chronic sinusitis. Clin Otolaryngol 1986;11:55-60.

MEDLINE

20. Benninger MS, Kaczor J, Stone C. Natural ostiotomy vs. inferior antrostomy in the management of sinusitis: an animal model. Otolaryngol Head Neck Surg 1993;109:1034-42.

MEDLINE

Publishing and Reprint Information

TOP

- *From the Departments of ^aOtorhinolaryngology and ^bRadiology, Tohoku University School of Medicine, Sendai, Japan.*
- *Received for publication July 25, 1995.*
- *Revised May 30, 1996.*
- *Accepted for publication June 5, 1996.*
- *Reprint requests: Katsuhisa Ikeda, MD, Department of Otorhinolaryngology, Tohoku University School of Medicine, 1-1 Seiryō-machi, Aoba-ku, Sendai 980-77, Japan.*
- **1/1/75637**

- *Copyright © 1997 by Mosby–Year Book, Inc.*