Mucociliary Transport and Histologic Characteristics of the Mucosa of Deviated Nasal Septum

Yong Ju Jang, MD, PhD; Na-Hye Myong, MD, PhD; Keun Hwan Park, MD; Tae Woo Koo, MD; Han-Gyun Kim, MD

Objective: To investigate differences in mucociliary clearance, histologic characteristics, and surface structure of the bilateral nasal septal mucosa in patients with nasal septal deviation.

Design: Mucociliary transport was measured by saccharin clearance time in both nasal cavities of 20 patients with nasal septal deviation. Their septal mucosae were taken during septoplasty, and the ciliary population was studied by scanning electron microscopy. Histologic differences in the lamina propria of septal mucosae were compared under a light microscope.

Results: The concave side showed longer saccharin clearance time than the convex side and revealed much more severe loss of cilia. Inflammatory cells more heavily infiltrated the concave side, and seromucinous glands were less densely distributed.

Conclusion: Concave-side septal mucosae have impaired mucociliary transport, presumably due to ciliary loss, increased inflammation, and decreased density of the glandular acini.


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The severity of septal deviations, their location, shape, and complexity all influence airflow dynamics in the nasal cavity. Thus, in the bilateral nasal cavities of subjects with nasal septal deviation (NSD), a difference may occur in the amount of airflow and resistance. In response to the difference in airflow dynamics between nasal cavities in NSD, a compensatory hypertrophy of the nasal mucosa on the side of the nose opposite the major septal deviation is often found. In addition to the compensatory hypertrophy, an impaired mucociliary clearance, higher incidence of ostiomeatal complex obstruction, and increased incidence of sinusitis have been reported in subjects with NSD. Interestingly, sinusitis has been reported to be more severe in the concave side than in the convex side, although a significant association with ethmoid sinus disease on the convex side has been reported. Ostiomeatal complex obstruction and resultant sinusitis in the direction of septal angulation were attributable to nasal septal deformity. However, contralateral ostiomeatal complex obstruction was suggested to be related to middle-turbinate and lateral-nasal-wall abnormalities, which appeared with increased frequency on the side opposite the septal deviation.

Nasal mucociliary clearance is a fundamental function required to maintain the health and defense of the nose. The clinician should suspect a disorder of mucociliary clearance in a patient who has rhinosinusitis. In the present study, we hypothesized that the nasal cavities of both sides in NSD have different mucociliary clearances, and this difference may be responsible for varying symptoms and increased incidence and severity of sinusitis in the side opposite the septal deviation. To test this hypothesis, we investigated the difference in saccharin clearance time (SCT) between nasal cavities. We also further investigated the difference between the concave- and convex-side mucosa with respect to anatomical factors such as ciliary population and the density of inflammatory cells and seromucous glands, which can affect the mucociliary transport.

While the mean SCT of the concave-side septal mucosa was significantly longer than that of the convex nasal cavity in the patients with NSD (P = .02), the SCT was...
PATIENTS AND METHODS

The study was performed with the approval of the Dangkook University Hospital ethics committee, and all the subjects gave written informed consent. From July 1999 to February 2000, we observed 20 patients (12 men and 8 women), ranging in age from 21 to 40 years (mean ± SD age, 32.8 ± 15.23 years), who underwent septoplasty for symptomatic NSD, which was diagnosed by endoscopy and acoustic rhinometry. Thirteen patients showed deviation to the left side, and the remaining 7 patients showed deviation to the right. All patients had C-shaped anteroposterior deviation and C-shaped cephalocaudal septal deviation on endoscopic examination. Patients who had minor spurs or severe S-shaped septal deviation were excluded. In acoustic rhinometric examination, all patients revealed a difference of greater than 0.4 cm² between nasal cavities in the nondecongested minimal cross-sectional area. Each member of the control group demonstrated a straight septum on endoscopic examination and showed a difference in minimal cross-sectional area of less than 0.2 cm², as determined by acoustic rhinometry. The study population had not experienced upper respiratory tract infection in the previous 2 months, and showed normal sinus radiography characterized by the absence of sinus opacity, mucosal thickening, and air-fluid level in the posteroanterior view and the Water view. They showed negative results in a skin-prick test using 40 common inhalant allergens, as determined by a mean wheal size smaller than 2 mm in diameter and an area less than 25% that of a reference histamine reaction.

During the preoperative evaluation, saccharin tests of both nasal cavities were conducted separately on consecutive days. A 1-mm-diameter or quarter fragment of a saccharin tablet was placed on the anterior end of the septal mucosa and an area less than 25% that of a reference histamine patch, version 6.04 (SAS Institute, Cary, NC). The difference in the degree of ciliary population, number of inflammatory cells was 52.9 ± 4.95 in the convex side of the septal mucosa and 102.5 ± 51.8 in the concave-side septal mucosa (Figure 1B). The average score in the grading of ciliated mucosa was 9.6 ± 4.37 in the convex side of the septal mucosa and 12.36 ± 4.83 in the concave side (Figure 1A).

During the septoplasty, samples of septal mucosae approximately 0.5 × 0.5 cm were taken from the point 2 cm posterior to the nostril and 1.5 cm inferior to the nasal dorsum. Each mucosal sample was divided in 2: one for scanning electron microscopic examination and the other for light microscopic examination. For scanning electron microscopic study of the surface structure, mucosal specimens were immediately immersed in 2.5% glutaraldehyde in 0.1M cacodyl buffer (pH 7.4) at room temperature. After several hours of fixation, they were rinsed in 0.1M cacodyl buffer with 1.0M sucrose and postfixed in 1% osmium tetroxide in 0.1M cacodyl buffer (pH 7.4) at 4°C. The specimens were dehydrated in graded ethanol series and then dried in a critical point drier (HCP-2; Hitachi Co, Tokyo, Japan). Samples were coated with gold in a sputter coater (E 106; Hitachi Co) with 2.5-kV acceleration voltage in an argon atmosphere with a current of 20 mA for 1 minute. Samples were examined under a scanning electron microscope (S-2500; Hitachi Co) at 15.0 kV in a random manner. The degree of ciliary population was graded as 1 (no cilia), 2 (ciliated mucosa occupying less than 30% of the epithelial surface), 3 (ciliated mucosa occupying 30% to 60% of the surface), or 4 (ciliated mucosa occupying more than 60% of the epithelial surface). To evaluate the degree of ciliary population, the proportional area of the ciliated epithelial surface was estimated by 2 separate investigators on 5 randomly selected mucosal surfaces for each specimen under ×1500 magnification.

For light microscopic examination, the remaining mucosal pieces were fixed in 10% formalin, embedded in paraffin, and stained with hematoxylin-eosin. The histologic characteristics observed included the distribution of the nasal glands and infiltration of inflammatory cells. The number of all types of inflammatory cells was noted in 5 randomly selected areas of both the subepithelial layer and the interglandular connective tissue at ×400 magnification. The distribution of nasal glandular tissues was evaluated in the portions of lamina propria deeper than the subepithelial layer by counting the number of glandular acini on the randomly selected 5 areas at ×400 magnification. The glandular acini were also classified into serous and mucinous types. The serous and mucinous glands were characterized by their amorphophilic granular cytoplasm and pale blue or clear cytoplasm, respectively. Light microscopic examination was also conducted in a blind manner by 2 investigators. The difference in SCT was statistically tested by 1-way analysis of variance using the PC-SAS statistical package, version 6.04 (SAS Institute, Cary, NC). The difference in the degree of ciliary population, number of inflammatory cells, and number of glandular acini was statistically tested using the t test.

Table 1. Mean ± SD Saccharin Clearance Time (SCT) in Bilateral Nasal Mucosa of Patients With Nasal Septal Deviation (NSD) and Control Subjects

<table>
<thead>
<tr>
<th>Patient Group</th>
<th>Nasal Cavity</th>
<th>Mean SCT, min</th>
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<tbody>
<tr>
<td>NSD (n = 20)</td>
<td>Concave side</td>
<td>16.52 ± 8.06</td>
</tr>
<tr>
<td></td>
<td>Convex side</td>
<td>12.36 ± 4.83</td>
</tr>
<tr>
<td>Control (n = 15)</td>
<td>Right side</td>
<td>11.36 ± 4.33</td>
</tr>
<tr>
<td></td>
<td>Left side</td>
<td>11.06 ± 3.53</td>
</tr>
</tbody>
</table>

not significantly different between both nasal cavities in the control group. The SCT in the convex side of patients with NSD showed no significant difference with those of the septal mucosa of the right and left side of the normal group, respectively (P > 0.05) (Table 1).

In scanning electron microscopic examination, the concave-side nasal mucosa (Figure 1A) showed less dense ciliary population than the contralateral septal mucosa (Figure 1B). The average score in the grading of ciliary population was significantly lower in the concave sides, indicating more severe loss of cilia (P = 0.005) (Table 2).

The mean ± SD number of infiltrating inflammatory cells was 52.9 ± 4.95 in the convex side of the septal mucosa and 102.5 ± 51.8 in the concave-side septal mucosa (P = 0.003) (Figure 2). Infiltrating inflammatory cells were largely lymphocytes, histiocytes, plasma cells, and neutrophils.
The mean ± SD number of submucosal glandular acini was 97.2 ± 16.9 on the convex-side septal mucosa and 66.6 ± 18.7 on the concave-side septal mucosa, indicating sparse distribution of glandular acini in the concave-side septal mucosa (Figure 3). Among the total glandular acini, the respective numbers of mucinous glands and serous glands also were smaller in the concave-side mucosa ($P$/.001).

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**COMMENT**

In the present study, the SCT was longer in the concave nasal cavity than in the convex nasal cavity. Previous investigators have also reported significantly increased SCT in patients with NSD. In our study, we compared the MCT of the each nasal cavity and found impaired SCT in only the concave nasal cavity.

ciliary transport (MCT) was normalized 3 months after septoplasty. In contrast, Passali et al found that times for MCT in patients with NSD were practically identical to those of the control group. This discrepancy in the results of the previous studies may exist because the MCTs of the bilateral nasal cavities were not considered independently. However, in our study, we compared the MCT of the each nasal cavity and found impaired SCT in only the concave nasal cavity.

In our study, the concave-side septal mucosae revealed more severe loss of cilia under scanning electron microscopic examination. Ultrastructural changes of respiratory mucosa can result from acute and chronic in-
Infections. In experimental study in which one nostril is closed and the other is open, ciliary loss in the open cavity has been demonstrated. Accordingly, in our study, the increased loss of epithelial cilia in the concave-side septal mucosa might have been caused by increased airflow.

In the present study, infiltration of inflammatory cells was more prominent in the concave-side septal mucosa than in the convex. The exact mechanism for this occurrence is not understood, but it may be that a spontaneous inflammatory process not related to allergy or infections is not understood, but it may be that a spontaneous inflammatory process not related to allergy or infection may be brought about in the more open nasal cavity by increased airflow.

In the study by Inagi regarding the histologic changes in the mucous membrane of the human deviated nasal septum, the mucosa of the concave side collected from 74 cadavers consistently showed hypertrophic change of the area of mucous glands and the thickness of the mucoperiosteum. However, in our study, the distribution of seromucinous glands was less compact in the concave-side septal mucosa than on the convex side. The different result regarding the distribution of nasal glandular tissue between the 2 studies may result from the different study populations. In our study, the study materials were septal mucosa taken from symptomatic living human subjects with NSD. Thus, our result may better represent the true histologic features of subjects with NSD complaining of stuffy nose that necessitates surgical treatment. As for the decreased distribution of the glandular tissue in our study, it is possible that a chronic inflammatory process of the concave-side septal mucosa, as demonstrated in our study as an increased infiltration of inflammatory cells, may lead to stromal proliferation and fibrosis of the lamina propria, resulting in relative paucity of the glandular acini.

The MCT represents the first barrier of the nasal fossae and paranasal sinuses against various biological and physical insults. Differences in MCT rates between different sites in the nose depend on ciliary beat frequency, density of the ciliary population, length of the cilia, and mucus quality. The results of our study, which revealed impaired MCT in the concave nasal cavity, can certainly be explained by the decreased ciliary population on the ipsilateral side, indicating a loss of mucociliary machinery. Additionally, a changed property of mucus covering the epithelium that can result from increased inflammatory infiltrates and reduced distribution of glandular tissue (not examined in our study) might have contributed to the impaired MCT in the concave-side septal mucosa.

In conclusion, the results of our study suggest that NSD is not a simple affliction resulting only in a mechanical alteration of nasal airflow in the nasal cavity, but a more complex disease process presenting with impaired mucociliary clearance in the concave-side mucosa that can predispose a patient to increased incidence and severity of sinusitis in the side opposite the NSD. The results of this study also indicate that the concave-side septal mucosa has impaired MCT compared with that of the convex side, probably due to ciliary loss, increased inflammation, and decreased density of the glandular acini.

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Correction

In the article by Jang et al titled “Mucociliary Transport and Histologic Characteristics of the Mucosa of Deviated Nasal Septum” in the April 2002 issue of the ARCHIVES (2002;128:421-424), the legend for Figure 1 was incorrect. It should have read as follows:

Figure 1. In scanning electron micrographs of the septal mucosa from each nasal opening in a patient with nasal septal deviation, the concave side (A) shows sparsely populated cilia (original magnification ×1990), and the convex side (B), densely populated cilia (original magnification ×2180).

We regret the error.