Turkish Archives of Otorhinolaryngology
Turk Arch Otorhinolaryngol

# Nasal Mucociliary Clearance Time in Symptomatic versus Asymptomatic Deviated Nasal Septum: A Comparative Analysis

Original Investigation

Urmila Gurung, Rahul Bathwal, Kripa Dongol

Tribhuvan University Teaching Hospital - Maharajgunj Medical Campus, Institute of Medicine, Department of Ear, Nose, and Throat-Head and Neck Surgery, Kathmandu, Nepal

## Abstract

**Objective:** Nasal mucociliary clearance is the first barrier defense mechanism that protects the respiratory system. This study aimed to assess nasal mucociliary clearance time (NMCT) using saccharine test in patients with symptomatic and asymptomatic deviated nasal septum (DNS).

**Methods:** This was a prospective study conducted in a tertiary center from February 2022 to July 2023. A total of 40 patients, including 20 symptomatic and 20 asymptomatic patients with DNS, were included. The Nasal Obstruction Symptom Evaluation scale was used to assess the severity of nasal obstruction in patients with symptomatic DNS. NMCT was measured by saccharine test in both the symptomatic and asymptomatic DNS patients. NMCT between these two groups was compared.

**Results:** There were 27 males and 13 females with a mean age of 28.53±7.86 years. Overall median NMCT was 7 minutes 30 seconds, with a similar duration (7 minutes 30 seconds) in patients with symptomatic DNS and 7 minutes and 15 seconds in asymptomatic patients. The difference in NMCT between the symptomatic and asymptomatic groups was not statistically significant. Similarly, it did not differ based on age, gender, or severity of the nasal obstruction.

**Conclusion:** Although NMCT was longer in patients with symptomatic DNS compared to those with asymptomatic DNS, no statistical difference was found. Additionally, NMCT remained within normal physiological limits in both. We thus conclude that NMCT remains unaffected regardless of whether the DNS patient is symptomatic or asymptomatic.

**Keywords:** Nose, mucociliary clearance, nasal septum, saccharine, respiratory system

***ORCID IDs of the authors:***
*U.G. 0000-0001-7640-0199*
*R.B. 0009-0004-7310-2638*
*K.D. 0000-0001-5108-6770*

***Cite this article as:*** *Gurung U, Bathwal R, Dongol K. Nasal mucociliary clearance time in symptomatic versus asymptomatic deviated nasal septum: a comparative analysis. Turk Arch Otorhinolaryngol. [Epub Ahead of Print].*

**Corresponding Author:**
Urmila Gurung, Assoc. Professor;
dr.urmila.gurung@gmail.com

**Received Date:** 05.06.2025
**Accepted Date:** 03.08.2025
**Epub:** 11.09.2025

**DOI:** 10.4274/tao.2025.2025-6-5

## Introduction

Mucociliary clearance of the nose is the first barrier defense mechanism that protects the respiratory system, especially the upper airway and the sinuses, against inhaled agents (1). Foreign bodies are trapped on the mucus layer and transported towards the pharynx by the ciliary beat, which acts like a conveyor belt (2,3). Alteration in the nasal mucociliary clearance time (NMCT) is often associated with the inflammatory conditions of the airway, such as allergic rhinitis, atrophic rhinitis,

chronic rhinosinusitis, asthma, and secondary to chronic exposure to environmental irritants, smoking, and post-nasal packing (4-6).

Deviated nasal septum (DNS) is most often asymptomatic, however, it may present with nasal obstruction, nasal discharge, smell disturbance, facial pain, and epistaxis, with nasal obstruction being the predominant symptom (2,7,8). The type and severity of the septal deviation can affect the aerodynamics in the nasal cavity. It can also impair mucociliary clearance due to increased mucus secretion, disruption of normal ciliary activity, cilia exfoliation, and epithelial injury (8). The effect of DNS on NMCT remains controversial (7).

An altered nasal mucociliary clearance could be contributory to a septal deviation being symptomatic. While most studies have focused on comparing NMCT between the concave and convex sides of symptomatic DNS pre- and post-operatively, with noted improvement in the NMCT post-septoplasty there is a lack of literature assessing any alteration in NMCT solely due to septal deviation without it being symptomatic (8,9). This study was thus conducted to assess for any alteration in NMCT in asymptomatic DNS or whether it differed based on whether the septal deviation was symptomatic or asymptomatic. NMCT was assessed using a widely accepted saccharine test.

## Methods

The study was conducted in the Department of Ear, Nose, and Throat-Head and Neck Surgery at Tribhuvan University Institute of Medicine, Teaching Hospital Kathmandu, Nepal, from February 2022 to July 2023. Ethical permission was obtained from Tribhuvan University Teaching Hospital, Institute of Medicine Institute of Medicine Institutional Review Committee [approval no: 286 (6-11) E2/078/079, date: 11.01.2022]. Written informed consent was obtained from the patients for enrollment in the study.

The sample size was calculated using the two-sample comparison of means (equal variances) formula, where n per group $=[2\times(Z_{1-\alpha/2}+Z_{1-\beta})^2\times sp^2]/\Delta^2$. With $\alpha=0.05$ (two-sided; $Z_{1-\alpha/2}=1.96$) and 95% power ($\beta=0.05$; $Z_{1-\beta}=1.645$), pooled standard deviation (SD) sp=2.545, and target mean difference $\Delta=3.45$ from Chandra and Bylappa (10), the required size was ≈14 per group. With the addition of 20% potential dropout, it was ≈17 per group. To further increase the statistical power, 20 patients per group were included, for a total of 40.

Patients aged 18 years or more, with symptomatic DNS were taken as one group, and those without symptoms as another. Nasal obstruction was taken as the predominant symptom of septal deviation. The severity of the nasal obstruction amongst the symptomatic DNS group was assessed using the Nasal Obstruction Symptom Evaluation (NOSE) scale form (11). It was categorized as mild (range, 5-25), moderate (range, 30-50), severe (range, 55-75), or extreme (range, 80-100) nasal obstruction, based on the response score on the NOSE scale form (12). Septal deviation of any type, with or without contralateral compensatory inferior turbinate hypertrophy, was included. Diagnostic nasoendoscopy was done to rule out any other concomitant pathology.

Patients with previous nasal surgery, concomitant nasal polyposis, allergic rhinitis, chronic rhinosinusitis, acute upper respiratory tract infection, loss of taste and smell sensation, smokers, use of pharmacological agents affecting nasal mucociliary clearance within three months, namely nasal decongestants, beta-adrenergic agonist, anti-histaminic, steroids, or any systemic disease likely to impair ciliary activity were excluded.

Each patient was comfortably seated in a chair and asked to gently blow their nose and slightly extend their head (~10 degrees). The saccharine test was done on the convex side of DNS. After visualizing the anterior nasal cavity with a Killian's speculum, the saccharine crystals, sized around 0.5 mm, were placed on the inferior turbinate one cm posterior to the anterior end of inferior turbinate as described previously (2,6,13-15). This was to avoid the area on the anterior end of the inferior turbinate where cilia tend to beat in an anterior direction (14). The patients were instructed to swallow every 60 seconds (sec) to reduce the time latency of taste perception. Furthermore, they were instructed to maintain their natural breathing through the nose and avoid getting up, talking, coughing, sneezing, or manipulating their nose. The flavor and taste of the particle were not disclosed. NMCT was taken as the duration between the saccharine crystal placement on the inferior turbinate and the first perception of taste. Non-perception of taste, even after 60 minutes, or accidental expulsion of the saccharine particle, mostly due to sneezing, would terminate the test.

### Statistical Analysis

Statistical tests were done using the Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.). All quantitative variables were estimated using measures of central tendency and measures of dispersion. Data normality was tested using the Kolmogorov-Smirnov test for continuous variables. The values of NMCT were not normally distributed (p=0.013). Comparison of mean age, gender, and side of septal deviation between the two groups was done using an independent samples t-test, a chi-squared test, and Fisher's exact test, respectively. Comparison of NMCT between the two groups was done using the Mann-Whitney U test, whilst comparison of NMCT based on gender and severity of the NOSE scale was done using the Mann-Whitney U and Kruskal-Wallis tests, respectively. A p-value <0.05 was considered statistically significant.

## Results

### Demographics

There were 40 patients (27 males and 13 females), 20 each in the symptomatic and asymptomatic DNS groups. Their ages ranged from 18 to 50 years (mean 28.53±7.86). There were no statistically significant differences in age and gender distribution in the symptomatic and asymptomatic groups. Out of 40 patients, 26 (65%) had left-sided while 14 (35%) had right-sided septal deviation. Seven (17.5%) had contralateral inferior turbinate hypertrophy. Among the symptomatic patients, the majority had an obstructive type of DNS with moderate and severe nasal obstruction (80%) (Table 1).

### Nasal Mucociliary Clearance Time

The overall NMCT ranged from 2 minutes (min) 30 sec to 16 min (median 7 min 30 sec). In patients with symptomatic DNS, it ranged from 4 to 16 min (median 7 min 30 sec) whilst in asymptomatic DNS, it ranged from 2 min 30 sec to 12 min (median 7 min 15 sec), with no statistically significant differences (p=0.455) (Table 2). There were no statistical differences in NMCT based on gender and severity of nasal obstruction among symptomatic patients (Table 3).

**Table 1.** Demographics and clinical features of patients in the two groups

| Parameters | | Symptomatic DNS (n=20) | Asymptomatic DNS (n=20) | p-value |
|---|---|---|---|---|
| Mean age (in years)±SD | | 29.4±9.38 | 27.65±6.08 | 0.939[a] |
| Gender | Male | 14 | 13 | 0.736[b] |
| | Female | 6 | 7 | |
| Side of septal deviation | Left | 15 (75%) | 11 (55%) | 0.320[c] |
| | Right | 5 (25%) | 9 (45%) | |
| Contralateral inferior turbinate hypertrophy | Left | 1 | 1 | |
| | Right | 2 | 3 | |
| Severity of nasal obstruction[d] | Mild | 2 (10%) | | |
| | Moderate | 9 (45%) | | |
| | Severe | 7 (35%) | | |
| | Extreme | 2 (10%) | | |

[a]: Independent samples t-test, [b]: Chi-squared test, [c]: Fisher's exact test, [d]: Based on NOSE scale, DNS: Deviated nasal septum, SD: Standard deviation, NOSE: Nasal Obstruction Symptom Evaluation

**Table 2.** Nasal mucociliary clearance time in patients with symptomatic and asymptomatic deviated nasal septum (n=40)

| Groups | Nasal mucociliary clearance time | | | |
|---|---|---|---|---|
| | Minimum | Maximum | Median | p-value |
| Symptomatic DNS (n=20) | 4 min | 16 min | 7 min 30 sec | 0.455* |
| Asymptomatic DNS (n=20) | 2 min 30 sec | 12 min | 7 min 15 sec | |
| Overall (n=40) | 2 min 30 sec | 16 min | 7 min 30 sec | |

*: Mann-Whitney U test, DNS: Deviated nasal septum

**Table 3.** Nasal mucociliary clearance time based on age, gender, and severity of nasal obstruction

| Parameters | | Nasal mucociliary clearance time | | | |
|---|---|---|---|---|---|
| | | Minimum | Maximum | Median | p-value |
| Age in years (n=40) | ≤40 (37) | 2 min 30 sec | 15 min | 7 min | 0.08[b] |
| | >40 (3) | 7 min | 16 min | 16 min | |
| Gender (n=40) | Male (27) | 2 min 30 sec | 16 min | 7 min | 0.168[b] |
| | Female (13) | 5 min | 16 min | 8 min 30 sec | |
| Severity of nasal obstruction[a] (n=20) | Mild (2) | 7 min | 10 min | 8 min 30 sec | 0.204[c] |
| | Moderate (9) | 4 min | 12 min 30 sec | 7 min 30 sec | |
| | Severe (7) | 5 min | 16 min | 6 min 30 sec | |
| | Extreme (2) | 15 min | 16 min | 15 min 30 sec | |

[a]: Based on NOSE scale, [b]: Mann-Whitney U test, [c]: Kruskal-Wallis test, NOSE: Nasal Obstruction Symptom Evaluation

## Discussion

Alterations in nasal mucociliary clearance, although not diagnostic, indicate the severity of the pathological condition in the respiratory system (4). The saccharine test, which was initially developed by Andersen et al. (16) in 1974, is invaluable as a screening test for mucociliary clearance. It is simple, economical, well-tolerated, and reproducible (13,15). Saccharine is soluble and spreads into the fluid layer of the mucus (17).

Caponnetto et al. (15) found consistent findings of NMCT when repeating the saccharine test thrice in 29 healthy individuals, demonstrating its reproducibility. The mean values (±SD) of NMCT were 7.085 (±2.19), 7.788 (±2.11), and 7.790 (±2.06) min at baseline, day 3, and day 30, respectively. The values were close to the mean pooled value of 9.42±3.04 min calculated in the systematic review by the same authors. It was well-tolerated with infrequent transient side effects like nasal itch, nasal irritation, and sneezing.

In our study, the procedure was well-tolerated. Three patients reported having a short-lived metallic taste before sensing the sweet sensation of the saccharine. Keeping in mind the notable change in the mucociliary clearance due to circadian rhythm, the procedure in our study was conducted in the morning, avoiding performing it past noon, when the mucociliary clearance is likely to alter (17).

The procedure was performed on the convex side since it was the side of nasal obstruction, avoiding concomitant inferior turbinate hypertrophy, which was noted in seven of our cases. Although Passàli et al. (17) reported normal NMCT in patients with inferior turbinate hypertrophy, skepticism remains that it may decrease mucociliary clearance (7). Performing saccharine test on either the concave or convex side has shown mixed findings. Berkiten et al. (7) found no difference in the NMCT between the convex (12.04±4.94) and the concave sides (10.30±4.99) amongst 50 patients (20 females and 30 males) with six different types of septal deviation based on the Baumann and Baumann classification. This was echoed by Polat and Dostbil (18) who also noted no difference in mucociliary clearance rate between the sides, assessed using rhinoscintigraphy, in both symptomatic and asymptomatic patients. However, Jang et al. (9) reported impaired mucociliary clearance on the concave side (16.52±8.06) as compared to the convex side (12.36±4.83), attributing this to ciliary loss, increased inflammation, and decreased density of glandular acini on the concave side of the septum noted on histological examination. Yigit et al. (19) found that mucociliary clearance was faster on the concave side, slower on the obstructed side, but comparable to that of the control, so they concluded that septal deviation did not alter mucociliary clearance (19). On the contrary, Ginzel and Illum (2) opined that the epithelium at the site of deviation becomes highly differentiated, resulting in faster mucociliary clearance on the convex side. However, Ulusoy et al. (20) noted impaired nasal mucociliary clearance on both sides of septal deviation in both symptomatic and asymptomatic, non-smoking patients. A notable improvement was seen in symptomatic patients after septoplasty.

Normal NMCT ranges between 7 and 15 min, whilst values greater than 20 min are considered pathological (7,15). Some have reported 11 min as the lower and 17.45 min as the upper limit of the normal range (8,21). In the study by Uslu et al. (8), the NMCT amongst 15 patients with DNS was higher than the normal (21.25 to 29.45; mean 26.25±9.45) which returned to a normal range post-septoplasty. Similarly, Jang et al. (9) noted altered MCT amongst DNS patients (mean NMCT 22.50±2.70) which further worsened amongst smokers (mean 26.35±1.78). Smoking alters the NMCT by changing the viscoelasticity of the mucus layer and also by its cilia toxic effect (9).

In our study, the overall NMCT, along with the values for both symptomatic and asymptomatic DNS, was well within 20 minutes, the cut-off point that separates normal from dysfunctional MCT. None of our patients were smokers. Based on our findings, we found no abnormalities in NMCT or significant differences between symptomatic and asymptomatic DNS. The same was observed for age, gender, and the severity of nasal obstruction in symptomatic patients. Ginzel and Illum (2) reported no significant differences in NMCT between the obstructed and non-obstructed sides, indicating no difference between the symptomatic and asymptomatic sides. Ho et al. (22) found significant differences in NMCT in patients aged under 40 years and over 40 years (9.3±5.2 min versus 15.4±5.0 min, respectively), unlike Kao et al. (23) who noted no differences based on age. The latter had taken 59 years as the cut-off age to categorize the group into two. However, both studies agreed on the NMCT remaining similar based on gender (22,23). Some patients in our study had an NMCT as low as 2 min 30 sec. This could be due to ethnic variation, as NMCT has been noted to vary based on ethnicity (23). Kao et al. (23) found relatively shorter NMCT amongst healthy Chinese adults as compared to published data involving other ethnicities.

Similar to our study, the NMCT values reported by Berkiten et al. (7) and Jang et al. (9) were well under 20 min. This also corresponds to the findings of Yigit et al. (19) who indicated that septal deviation did not pathologically alter mucociliary clearance. As per Yigit et al. (19), obstructive pathologies like DNS can affect the airflow; however, if the mucosal function is maintained, inflammatory mediators that are likely to increase the viscoelasticity of the mucus are not released and thus mucociliary activity is preserved. Assessing NMCT by saccharine and charcoal powder, it remained within the physiological range for patients with septal deviations, in contrast to the increased time in patients with chronic

sinusitis in the study by Passàli et al. (17). In contrast, Dogan et al. (24) observed that severe septal deviation (types 4 and 6 according to the Baumann and Baumann classification) had impaired mucociliary clearance, which improved following septoplasty. This suggested the likeliness of specific structural features of the deviation to alter nasal mucociliary clearance. Similarly, Polat and Dostbil (18) found that the mucociliary clearance rate differed significantly between symptomatic and asymptomatic, with the former showing a notable improvement three months after surgery. Interestingly, Kamani et al. (25) observed that the NMCT values for both groups were less than 20 minutes, while finding a difference between the symptomatic and asymptomatic DNS in the saccharine-dye test. Furthermore, their study revealed that the ultrastructural ciliary structure of the nasal mucosa remained unchanged irrespective of symptoms.

The strength of this study was the assessment of the NMCT in asymptomatic DNS and its comparison with that of symptomatic DNS. Such an assessment has not been made in our context, so the findings of our study can serve as a baseline for further research. The environmental factors, such as air temperature and humidity during the procedure, which were likely to alter the result, were beyond our control when performing the saccharine test (23). Standardizing the environmental conditions where such tests are carried out is recommended to obtain reproducible results.

Considering that NMCT was within physiological limits in both groups, and there were no statistical differences between symptomatic and asymptomatic DNS in our study, septal deviation-related symptoms, mainly nasal obstruction, do not necessarily reflect impaired mucociliary transport. So, the decision for septoplasty for DNS is guided by the patient's symptoms without a need for a pre-operative NMCT assessment.

## Conclusion

Although NMCT was longer in patients with symptomatic DNS compared to those with asymptomatic DNS, no statistical differences were found. Additionally, NMCT remained within normal physiological limits regardless of whether the DNS was symptomatic or not. Furthermore, it did not differ based on age, gender, or severity of nasal obstruction. Thus, NMCT remains unaffected regardless of whether a patient with a DNS is symptomatic or asymptomatic.

### Ethics

**Ethics Committee Approval:** Ethical permission was obtained from Tribhuvan University Institute of Medicine Institutional Review Committee [approval no: 286 (6-11) E2/078/079, date: 11.01.2022].

**Informed Consent:** Written informed consent was obtained from the patients for enrollment in the study.

### Footnotes

### Authorship Contributions

Surgical and Medical Practices: U.G., R.B., K.D., Concept: U.G., R.B., K.D., Design: U.G., R.B., K.D., Data Collection and/or Processing: U.G., R.B., K.D., Analysis and/or Interpretation: U.G., R.B., K.D., Literature Search: U.G., R.B., K.D., Writing: U.G., R.B., K.D.

**Conflict of Interest:** The authors declare that they have no conflict of interest.

**Financial Disclosure:** The authors declare that this study has received no financial support.

**Main Points**

- Patients with deviated nasal septum had nasal mucociliary clearance times that remained within the normal range, indicating preserved mucociliary function.
- Nasal mucociliary clearance times did not differ significantly between symptomatic and asymptomatic patients, so a symptomatic deviated nasal septum may not necessarily indicate impaired mucociliary function.
- Age, gender, and severity of nasal obstruction did not alter nasal mucociliary clearance times, suggesting these variables may not affect the mucociliary clearance of the nose.

## References

1. Cohen NA. Sinonasal mucociliary clearance in health and disease. Ann Otol Rhinol Laryngol Suppl. 2006; 196: 20-6. [Crossref]
2. Ginzel A, Illum P. Nasal mucociliary clearance in patients with septal deviation. Rhinology. 1980; 18: 177-81. [Crossref]
3. Karaman M, Tek A. Deleterious effect of smoking and nasal septal deviation on mucociliary clearance and improvement after septoplasty. Am J Rhinol Allergy. 2009; 23: 2-7. [Crossref]
4. Pandya VK, Tiwari RS. Nasal mucociliary clearance in health and disease. Indian J Otolaryngol Head Neck Surg. 2006; 58: 332-4. [Crossref]
5. Sakakura Y, Ukai K, Majima Y, Murai S, Harada T, Miyoshi Y. Nasal mucociliary clearance under various conditions. Acta Otolaryngol. 1983; 96: 167-73. [Crossref]
6. Shusterman D. A simplified technique for evaluating nasal mucociliary clearance via saccharin transit time. Int Forum Allergy Rhinol. 2020; 10: 572-4. [Crossref]
7. Berkiten G, Kumral TL, Saltürk Z, Atar Y, Yildirim G, Uyar Y, et al. Effect of deviated nasal septum type on nasal mucociliary clearance, olfactory function, quality of life, and efficiency of nasal surgery. J Craniofac Surg. 2016; 27: 1151-5. [Crossref]

8. Uslu H, Uslu C, Varoglu E, Demirci M, Seven B. Effects of septoplasty and septal deviation on nasal mucociliary clearance. Int J Clin Pract. 2004; 58: 1108-11. [Crossref]
9. Jang YJ, Myong NH, Park KH, Koo TW, Kim HG. Mucociliary transport and histologic characteristics of the mucosa of deviated nasal septum. Arch Otolaryngol Head Neck Surg. 2002; 128: 421-4. [Crossref]
10. Chandra SB, Bylappa KA. A comparative study of effect of deviated nasal septum on nasal mucociliary clearance and to comprehend the effect of septal and turbinate surgeries on restoring the mucociliary clearance. Int J Otorhinolaryngol Head Neck Surg. 2018; 4: 764-69. [Crossref]
11. Stewart MG, Witsell DL, Smith TL, Weaver EM, Yueh B, Hannley MT. Development and validation of the nasal obstruction symptom evaluation (NOSE) scale. Otolaryngol Head Neck Surg. 2004; 130: 157-63. [Crossref]
12. Lipan MJ, Most SP. Development of a severity classification system for subjective nasal obstruction. JAMA Facial Plast Surg. 2013; 15: 358-61. [Crossref]
13. Stanley P, MacWilliam L, Greenstone M, Mackay I, Cole P. Efficacy of a saccharin test for screening to detect abnormal mucociliary clearance. Br J Dis Chest. 1984; 78: 62-5. [Crossref]
14. Rutland J, Cole PJ. Nasal mucociliary clearance and ciliary beat frequency in cystic fibrosis compared with sinusitis and bronchiectasis. Thorax. 1981; 36: 654-8. [Crossref]
15. Caponnetto P, Emma R, Benfatto F, Ferlito S, Gulino A, Maniaci A, et al. Saccharin test: methodological validation and systematic review of the literature. Ear Nose Throat J. 2024; 103: 494-507. [Crossref]
16. Andersen I, Camner P, Jensen PL, Philipson K, Proctor DF. A comparison of nasal and tracheobronchial clearance. Arch Environ Health. 1974; 29: 290-3. [Crossref]
17. Passàli D, Ferri R, Becchini G, Passàli GC, Bellussi L. Alterations of nasal mucociliary transport in patients with hypertrophy of the inferior turbinates, deviations of the nasal septum and chronic sinusitis. Eur Arch Otorhinolaryngol. 1999; 256: 335-7. [Crossref]
18. Polat C, Dostbil Z. Evaluation of the nasal mucociliary transport rate by rhinoscintigraphy before and after surgery in patients with deviated nasal septum. Eur Arch Otorhinolaryngol. 2010; 267: 529-35. [Crossref]
19. Yigit O, Akgul G, Alkan S, Uslu B, Dadas B. Changes occurring in the nasal mucociliary transport in patients with one-sided septum deviation. Rhinology. 2005;43: 257-60. [Crossref]
20. Ulusoy B, Arbag H, Sari O, Yöndemli F. Evaluation of the effects of nasal septal deviation and its surgery on nasal mucociliary clearance in both nasal cavities. Am J Rhinol. 2007; 21: 180-3. [Crossref]
21. Antunes MB, Cohen NA. Mucociliary clearance--a critical upper airway host defense mechanism and methods of assessment. Curr Opin Allergy Clin Immunol. 2007; 7: 5-10. [Crossref]
22. Ho JC, Chan KN, Hu WH, Lam WK, Zheng L, Tipoe GL, et al. The effect of aging on nasal mucociliary clearance, beat frequency, and ultrastructure of respiratory cilia. Am J Respir Crit Care Med. 2001; 163: 983-8. [Crossref]
23. Kao CH, Jiang RS, Wang SJ, Yeh SH. Influence of age, gender, and ethnicity on nasal mucociliary clearance function. Clin Nucl Med. 1994; 19: 813-6. [Crossref]
24. Dogan R, Tugrul S, Erdoğan EB, Eren SB, Ozturan O. Evaluation of nasal mucociliary transport rate according to nasal septum deviation type. Int Forum Allergy Rhinol. 2016; 6: 768-73. [Crossref]
25. Kamani T, Yilmaz T, Surucu S, Turan E, Brent KA. Scanning electron microscopy of ciliae and saccharine test for ciliary function in septal deviations. Laryngoscope. 2006; 116: 586-90. [Crossref]