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Evaluation of the nasal mucociliary transport rate by rhinoscintigraphy before and after surgery in patients with deviated nasal septum

Cahit Polat · Zeki Dostbil

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Abstract In this study, we have investigated the effect of nasal septal deviation (NSD) on nasal mucociliary activity and how does a septoplasty operation affecs the nasal mucociliary transport rate in the first and third months during the post-operative period. Twenty-two patients who were diagnosed with NSD and 22 healthy controls were studied using rhinoscintigraphy with Tc-99m-macroaggregated albumin (Tc-99m-MAA). On each case, the nasal mucociliary transport rate (NMTR) was measured pre-operatively only on five cases, on the first and third months of post-operative period. The NMTRs of patients with a deviated septum were significantly lower than the NMTRs of the healthy controls on both the convex and concave sides. Significant improvement was observed in the first post-operative month. On the concave and convex sides, the average postop third month post-operative NMTR value was higher than the first month post-operative NMTR values. It was concluded that the septoplasty operation improves reduced NMTRs after surgery. The effect of nasal surgery on nasal mucociliary activity may be more accurately evaluated in the third month than the first month of post-operative period.

Keywords Nasal septum · Septal deviation · Septoplasty · Mucociliary clearance · Rhinoscintigraphy

C. Polat
Department of Otorhinolaryngology-Head and Neck Surgery, Elazig Research and Training Hospital, Elazig, Turkey

Z. Dostbil (✉)
Department of Nuclear Medicine, Dicle University Medical Faculty, Diyarbakir, Turkey
e-mail: zekidostbil@yahoo.com

Introduction

The nasal septum is an important structure which has a supportive role and affects the intranasal airflow pattern [1]. The nasal septum contributes to the temperature and moisture of the inhaled air to make it more suitable for the body and filtrates air from particles by its ciliated mucosa [2, 3]. Mucociliary transport is the physiological process in which the mucus layer on ciliated cells is moved. Particles are transported toward the nasopharynx by means of nasal mucociliary activity (MCA). This MCA is a first line of defense mechanism for physical and biological insults in the nasal fossa, paranasal sinuses and lower respiratory tract. Nasal MCA depends on the number of cilia and the beat frequency, their coordinated movements, the amount of nasal fluid and viscoelastic properties [4].

Many in vivo and in vitro techniques have been used for the measurement of MCA [5, 6]. In vitro techniques such as stroboscopy, photon–electron techniques and phase contrast microscopy make the measurement via determination of the ciliary beat frequency. However, they are too expensive and not suitable for routine use. In vivo techniques such as saccharine, charcoal and radionuclides using rhinoscintigraphy have been also used by many researchers [4, 7]. These methods can be performed easily and not too expensive. Rhinoscintigraphy is an objective and sensitive method used in the follow-up of nasal and paranasal surgery, and in determining the effectiveness of drug therapy for various nasal pathologies [7, 8]. In rhinoscintigraphy, very small dosage of Tc-99m is used. This dosage gives only negligible gamma radiation exposure to the patients.

In many studies it has been shown that in addition to a deviated septum causing nasal obstruction, impairment of intranasal airflow, and turbulence [9, 10], a deviated septum negatively affects nasal MCA, likely due to ciliary loss, increased inflammation, and a decreased density in glandular acini [11]. Septoplasty operation has been performed in the treatment of NSD [12, 13].

In this study, we aimed to investigate the effect of surgery on MCA on the convex (deviated side) and concave sides (contralateral side) in the first and third months of post-operative period in patients with a deviated nasal septum.

Materials and methods

For the patient group, 22 subjects between the age of 13–48 years [13 men and 9 women, 21.09 ± 8.33 years (mean + SD)] with complaints of chronic nasal obstruction and who were diagnosed with NSD by means of anterior rhinoscopy and an endoscopic nasal examination by an 'ear nose and throat specialist', and 22 healthy subjects between the age of 14–48 years (11 men and 11 women, 24.5 ± 9.51 years) for the control group were included in this study between April and October 2008.

Before each test; detailed ear, nose, throat, head, and neck examinations were performed in all cases. Patients with allergic rhinitis, chronic sinusitis, concha bullosa, nasal polyposis, turbinate hypertrophy, acute upper respiratory tract infection, rhinosinusitis within the last 2 weeks, any systemic illnesses, lactation, and who were smoking, had any drug therapy within the last week and were pregnant were excluded from the study.

In the patient group, rhinoscintigraphy was performed on both the convex and concave sides before the septoplasty, in the first month after surgery and, in some patients with less improvement in MCA at the first month measurement, at the post-operative third month, and at any time on both nasal cavities with 2-day intervals in the control group. In this test, one droplet (~50 μCi) of Tc-99m-macroaggregated albumin (Tc-99m-MAA) (particle size ranged between 10 and 150 μm) was dripped on the floor of the nasal meatus approximately 1 cm behind the anterior end of the inferior turbinate with a 27 g syringe. In order to prevent application and interpretation diversity, all tests were performed by the same staff. The room temperature was stabilized at 21°C. In the supine position, images were obtained using a GE Infinia gamma camera system with a LEHR collimator. Detectors were set laterally. Before the test, each patient was informed about the test procedure and their written consent was obtained. Thirty-second dynamic images were obtained during 20 min. After the subjects were removed from the table, a plate on which there were two radioactive point sources apart 10 cm from each other was placed on the table where the patients put their heads. Then, a 30-s additional static image was taken. After the test was completed, the images were processed. The distance between the point where the radiopharmaceutical was dripped and the point where the particles reached the nasal cavity was measured on a straight line with a system computer. This value was corrected with respect to the 10 cm point image. Then, to determine the NMTR in mm/min, this length was divided by the time which had elapsed.

For statistical analyses, the '*t*-test for independent groups' was used in comparison of the control and patient groups, and the right and left side data. The '*t*-test for paired groups' was used for the data of the patient group for comparison. The first and third months post-operative data were compared by an ANOVA test, and P value <0.05 was accepted as statistically significant. Before starting the study, we obtained approval from the Elazig Training and Research Hospital Ethics Committee.

Results

The average NMTR of the convex side before surgery was 6.5 ± 3.04 mm/min (mean ± SD) and that of the concave side was 5.38 ± 2.94 mm/min (Table 1). There was no statistically significant difference between the two sides ($P = 0.222$). In the control group, we found that the average NMTR of the left side was 8.15 ± 2.46 mm/min, the average NMTR of the right side was 8.5 ± 2.61 mm/min, and the average NMTR of the right and left sides was 8.32 ± 2.44 mm/min (Table 2). There was no significant difference between the right and left side values of the control group ($P = 0.651$). In comparison, we found that the pre-operative NMTR values of the convex and concave sides were significantly lower than the healthy controls ($P = 0.035$ and $P < 0.001$, respectively). In the first month of the post-operative period, the average NMTR of the convex side was 8.64 ± 2.8 mm/min and the average NMTR of the concave side was 6.85 ± 2.76 mm/min (Table 1). When the pre- and post-operative first month values of the convex and concave sides were compared, we found that there were significant increases in both the convex and concave sides ($P < 0.001$ and $P < 0.001$, respectively). There was no significant difference between the first month post-operative NMTR values of both sides and that of the control group when compared ($P = 0.690$ and $P = 0.069$, respectively).

In five cases in whom we performed the test in the first and third months post-operatively, the average NMTRs of the convex side were 4.52 ± 1.56 mm/min in the pre-operative period, 5.79 ± 1.95 mm/min in the first month post-operatively, and 8.94 ± 1.94 mm/min in the third month post-operatively; whereas, the average NMTRs of the concave side were 3.07 ± 2.38 mm/min in the pre-operative period, 3.49 ± 2.23 mm/min in the first month

Table 1 Nasal mucociliary transport rates of patients with a deviated nasal septum

Case no	Age (years)	Gender	NMTR (mm/min)					
			Pre-op		Post-op first month		Post-op third month	
			Convex	Concave	Convex	Concave	Convex	Concave
1	17	F	6.41	3.42	6.84	3.62	10.87	7.14
2	19	M	11.36	6.68	13.52	8.88		
3	30	M	5.54	2.73	12.33	5.88		
4	28	M	3.85	2.28	8.6	6.83		
5	17	M	4.56	2.9	7.75	5.6		
6	18	M	6.78	8.36	7.8	8.9		
7	15	M	6.95	8.12	7.18	9.11		
8	34	F	1.6	1.29	2.36	1.48	6.74	7.04
9	18	M	6.55	4.45	10.84	6.72		
10	17	M	5.05	3.55	6.54	4.1	10.5	8.34
11	17	F	4.51	5.82	9.65	6.8		
12	14	F	11.4	12.86	11.65	12.9		
13	18	M	10.71	6.65	11.73	7.7		
14	18	F	1.41	4.09	4.8	8.98		
15	13	F	10.14	2.71	10.62	3.57		
16	22	F	10.72	6.97	12.44	7.56		
17	48	M	3.96	0.5	6.1	1.43	7.37	5.44
18	16	F	3.76	7.97	5.83	8.56		
19	17	F	5.62	6.63	7.13	6.85	9.25	8.15
20	17	M	7.19	8.15	8.27	9.44		
21	32	M	4.95	4.38	7.88	6.75		
22	19	M	10.06	7.94	10.28	9.13		
Mean ± SD	21.09 ± 8.33	M: 13, F: 9	6.50 ± 3.04	5.38 ± 2.94	8.64 ± 2.8	6.85 ± 2.76		

NMTR Nasal mucociliary transport rate, *convex* deviated side, *concave* contralateral side

post-operatively, and 7.22 ± 1.15 mm/min in the third month post-operatively (Table 3). When the first and third months post-operative NMTRs of the convex and concave sides were compared, some improvement was found on each side (Figs. 1, 2, 3).

Discussion

Mucociliary transport is an important defense mechanism against physical and biological insults in the nasal fossa and paranasal sinuses. Foreign particles and microorganisms in the air inspired are filtrated by means of the MCA [4, 5] and incidence of rhinosinusitis is increased in cases when the MCA is impaired [4, 14, 15]. NSD negatively affects the MCA, likely due to loss of cilia, increased inflammation, and decreased density of glandular acini [11]. Following a septoplasty, impairment of the MCA is improved with time [8, 9, 16].

In this study, some patients with deviated septum had left deviation and some had right deviation. In the control group, we did not find any significant difference between the NMTRs of the right and left nasal cavities ($P = 0.651$), so we compared the NMTR values of the patients with the average of the left and right side NMTRs of the control group. The NMTRs of patients with deviated septum were significantly lower than the healthy controls on both the convex and concave sides. In the first month post-operative measurements, we observed significantly higher NMTRs on both sides. Before the post-operative period tests, all of the patient's noses were examined endoscopically. In all cases, we observed improvement and there was no need for any revision procedures. In the cases in which the first month post-operative NMTR values showed little improvement, third month post-operative measurements were performed to determine if the improvement continued. Unfotunately, we could perform the test only in five cases for various reasons. We found that on the concave and convex sides, the average third month post-operative NMTR value was higher than the first month post-operative NMTR values.

We did not consider age and gender in choosing subjects for study since the age, gender, posture, and dripping point

Table 2 Control group

No	Age (years)	Gender	NMTR (mm/min)		
			Left	Right	Mean
1	15	F	10.53	9.42	9.97
2	47	M	6.9	5.25	6.07
3	14	M	10.3	10.7	10.5
4	33	M	9.63	7.65	8.64
5	28	F	6.92	7.38	7.15
6	28	M	11.85	10.77	11.31
7	21	F	7.4	10.95	9.17
8	19	F	13.15	13.37	13.26
9	25	M	6.65	6.35	6.5
10	14	F	5.58	6.73	6.15
11	29	M	8.56	9.17	8.86
12	16	M	10.48	11.46	10.97
13	19	F	5.77	8.78	7.27
14	20	F	7.46	8.14	7.8
15	18	F	5.27	5.54	5.4
16	22	M	7.94	7.55	7.74
17	17	M	8.63	8.14	8.38
18	26	F	2.47	2.63	2.55
19	35	F	5.93	5.91	5.92
20	19	M	9.17	8.82	8.99
21	48	F	8.22	9.15	8.68
22	26	M	10.54	13.17	11.85
Mean ± SD	24.5 ± 9.51	M: 11, F: 11	8.15 ± 2.46	8.5 ± 2.61	8.32 ± 2.44

NMTR: Nasal mucociliary transport rate

Table 3 Patients in whom NMTRs were measured in the first and third months post-operatively

No.	NMTR (mm/min)					
	Convex			Concave		
	Pre-op	Post-op first month	Post-op third month	Pre-op	Post-op first month	Post-op third month
1	6.41	6.84	10.87	3.42	3.62	7.14
2	1.6	2.36	6.74	1.29	1.48	7.04
3	5.05	6.54	10.5	3.55	4.1	8.34
4	3.96	6.1	7.37	0.5	1.43	5.44
5	5.62	7.13	9.25	6.63	6.85	8.15
Mean ± SD	4.52 ± 1.56	5.79 ± 1.95	8.94 ± 1.94	3.07 ± 2.38	3.49 ± 2.23	7.22 ± 1.15

NMTR Nasal mucociliary transport rate

in the nasal cavity have been shown not to affect the accuracy of rhinoscintigraphy [17, 18]. Patients who have any situation that affected or potentially affected the accuracy of rhinoscintigraphy, such as systemic illnesses, drug usage, recent upper respiratory tract infection, or smoking, were excluded from the study [19, 20].

There are various techniques to evaluate ciliary activity in the nasal mucosa. Techniques, such as stroboscopy, roentgenography, and photoelectron techniques, can evaluate ciliary activity and ciliary beat frequency. However, such techniques are expensive and not suitable for routine use [7]. Most often, the tests used to measure MCA are rhinoscintigraphy and the saccharin test. The latter is very simple and inexpensive. In this test, a saccharin solution is dripped in the nasal cavity. This substance is carried to the nasopharynx and causes the patient to sense a taste of sugar. The time interval between the dripping process and sensing the sugar taste is noted. The main disadvantages of this test are that the NMTR cannot be measured and rely on the patient's sense of taste. Rhinoscintigraphy can supply

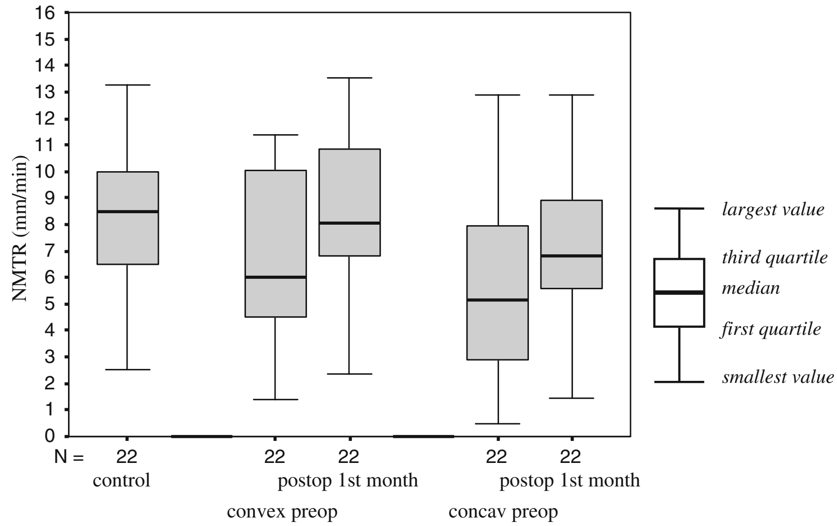

Fig. 1 Nasal mocociliary transport rate of patient and control group subjects

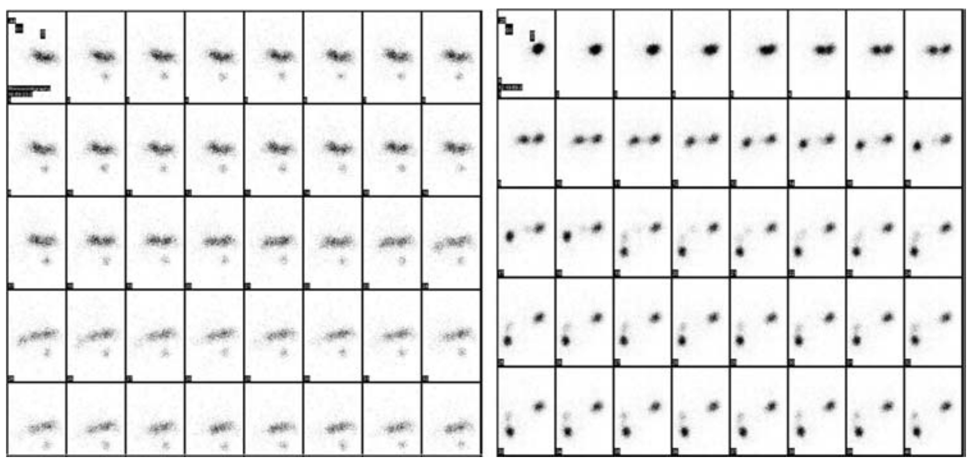

Fig. 2 Images of a patient with a deviated nasal septum are shown above. On the *left image*, the NMTR was measured as 4.56 mm/min before the septoplasty and on the *right image* in the first month postoperatively, a significant improvement in NMTR (7.75 mm/min) of same patient can be seen

objective and detailed information that allows quantitative analyses [16]. For this test, various radiopharmaceuticals (colloid solution, resin particles, and albumin particles) have been suggested. Currently, most researchers use Tc-99m-MAA for rhinoscintigraphy [7]. Rhinoscintigraphy has been shown to be a reliable, easily reproducible, and harmless method, so it may be used for follow-up examinations in patients who have had surgery of the nose and paranasal sinuses, and for drug therapy for rhinopathic conditions [7]. Thus, we also preferred Tc-99m-MAA for rhinoscintigraphy in this study.

In review of studies using rhinoscintigraphy in the most recent 14 years [5, 7, 9, 17, 21–23], we have seen that the average NMTRs of healthy individuals range between 4.48 and 17.94 mm/min (mean 8.92 mm/min). In all of these studies, individual NMTRs range between 1.2 and 28.7 mm/min. In our study, we obtained NMTRs ranging between 2.47 and 13.37 mm/min (mean 8.32 mm/min) in the healthy control group subjects. Our findings are in agreement with the literature. These different NMTR values found in various studies may be due to different environments, seasons, and non-standardization of test techniques.

Ulusoy et al. [9] studied 20 patients with nasal septal deviation and 20 healthy controls using Tc-99m-MAA rhinoscintigraphy. They found NMTRs of 17.94 ± 2.89 mm/min in the control group, 10.78 ± 3.53 mm/min on the convex side, and 10.24 ± 3.96 mm/min on the concave side in the patient group in the first month postoperatively. Our findings in this study were considerably lower (8.32 ± 2.44, 6.5 ± 3.04, and 5.38 ± 2.94 mm/min, respectively), although the same technique was used. This difference may be attributed to differences in computer analyses and the factors mentioned above. Juhani et al. [5] studied the asymmetry in the nasal mucociliary transport rate in 16 healthy subjects using rhinoscintigraphy and found a statistically significant difference ($P < 0.001$) between the right and left NMTRs. Thus, they concluded that there is asymmetry in the nasal mucociliary transport rates in the right and left nasal cavities of healthy individuals. We did not find any significant differences ($P = 0.651$) between the right and left side transport rates,

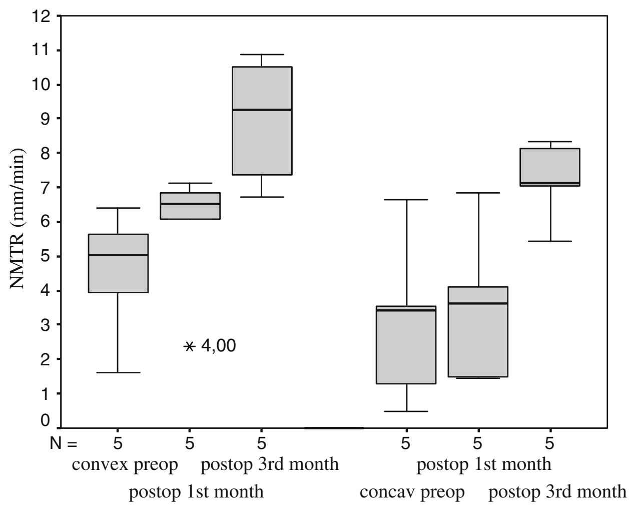

Fig. 3 Nasal mucociliary transport rate of patients in whom the test was performed in the first and third months post-operatively

consistent with Ulusoy et al. [9]. The different findings of Juhani et al. [5] may be the result of not using exactly same criteria as ours in choosing the healthy subjects in their study. Based on our study findings, we suggest that there is no asymmetry in the nasal mucociliary transport rates in the right and left nasal cavities of healthy individuals.

Regarding the effect of septoplasty on nasal MCA, some studies have repeated the measurement of NMTR in the first month post-operatively [9] and others have repeated the measurement of NMTE in the second month post-operatively [8]. In all of these studies, it has been shown that surgical correction of the nasal septum significantly improves the impaired MCA [8, 9, 16]. Ohashi et al. [24] have reported that complete recovery of the nasal mucosa after trauma has been suggested to occur after a post-operative period of 5 days if the basal cells and basement membrane are intact. When the entire nasal mucosa was injured mechanically, regenerative stratified epithelium covered the defect in 1 week, new ciliated cells appeared in 3 weeks, and complete regeneration was observed at 6 weeks. In our study, the NMTRs improved very little at the first month post-operatively. When we performed the test in five such cases at the third month post-operatively, we observed that the NMTRs were higher than before on each side. This finding suggested that repeating the test at the first month post-operatively in patients with nasal septal deviation may lead to false results in some cases.

Our study showed that NSD impairs nasal mucociliary activity. Septoplasty improves reduced NMTRs after surgery. The effect of nasal surgery on nasal mucociliary activity may be evaluated more accurately at the third month than the first month of post-operative period. The number of patients who were tested by rhinoscintigraphy in both first and third months post-operatively was five, which is insufficient. To understand if there is real statistically significant difference between NMTRs values of post-op first and third months, new studies should be planned on this issue with greater patient number.

Conflict of interest statement The authors declare that they have no financial relationship with any organization related to the research and no conflict of interest.

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