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ORIGINAL RESEARCH–FACIAL PLASTIC AND RECONSTRUCTIVE SURGERY

Role of nasal muscles in nasal valve collapse

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ABSTRACT

OBJECTIVE: This study was performed to determine the role of nasal muscle function in patients with dynamic or static nasal valve collapse by comparing the electromyographic activities of nasal muscles in healthy individuals.

STUDY DESIGN: Cross-sectional clinical study.

SETTING: Tertiary referral center.

SUBJECTS AND METHODS: Twenty adult patients with dynamic nasal valve collapse, 18 patients with unilateral static nasal valve stenosis (septum deviation), and 20 healthy adults were included in the study. The activity of their nasal muscles was measured by surface electromyography (EMG), and the results were compared for the patient and control groups.

RESULTS: No abnormal finding was found in any of the nasal muscles of the control group. In the majority of patients with dynamic nasal valve pathology, statistically significant functional disorders were detected in the m dilator naris anterior and m nasalis transversalis muscles compared with the controls. During inspiration and expiration in patients with static nasal valve pathology, some revealed muscular abnormities during inspiration. Normal muscle activation was observed in all of the patients during expiration.

CONCLUSION: Determination of agents involved in pathologies of the nasal valve region is necessary for planning appropriate treatment. The role of nasal muscles in dynamic nasal valve pathologies, which has not been previously recognized, should be considered. A more effective and adequate solution for the nasal sidewalls than static pathologies should be considered in these patients by taking into account the muscular activity disorders detected by EMG at the stage of surgical treatment.

The internal nasal valve was first defined by Mink in 1903 and has since been examined by many investigators. The internal nasal valve region is the narrowest anatomical point in the nasal airway, at which flow resistance is highest. Nearly two thirds of nasal airway resistance occurs in the internal nasal valve region. Nasal valve collapse occurs in 13 percent of the normal population.[1,2] During normal inspiration, negative pressure is transmitted to the nasal valves. In accordance with Bernoulli's principle, the velocity increases and the pressure decreases as air flows through this narrowed area. The inherent rigidity and strength of the nasal sidewall should be sufficient to resist collapse and maintain nasal patency, both at rest and with activity.[3] When incompetent, the resultant negative pressure causes narrowing of the valve.[4] The internal nasal valve region consists of several structures, including the aponeurotic system, muscle, cartilage, and inferior turbinate. For proper nasal valve function, all these regional structures must be both anatomically and functionally sufficient.[3]

The nasal muscles also have an important role in respiratory function.[3] Intrinsic and extrinsic nasal muscles assist in the rhythmic opening of the airways, playing an active role in inspiration and expiration.[1] Obstruction may occur in the internal nasal valve region because of static or dynamic causes. After excluding static causes that prevent breathing, the occurrence of obstruction as a result of functional unilateral or bilateral rhythmic inward movement of the lateral nasal walls during inspiration is defined as dynamic obstruction or collapse.[1,5]

The anatomical structure of the nasal valve region and its function in airflow vary among individuals.[6] Imaging methods, such as radiography, MRI, and CT, has limited benefit in evaluating internal nasal valve function.[7] Endoscopic evaluation of the anatomical structure of the nasal valve region in patients may be beneficial in the diagnosis and planning of surgical correction.[8] Patient history and a complete physical examination are key for the identification of causative factors.[1,5]

Determination of the epicenter of obstruction will facilitate identification of abnormalities related to the internal nasal valve, external nasal valve, and/or the intervalve area. Localizing the precise anatomical epicenter of collapse or clinical obstruction, and making the distinction between static narrowing of the airway, recognized at rest, and dynamic collapse of the sidewall with inspiration may contribute to appropriate treatment choice.[4] Cartilaginous alar and septal tissues resist deformation, and isometric contraction of alar dilator muscles during each inspiratory phase

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acts further to stabilize the airway lumen. Indeed, the strength of the dilator muscles can be clearly demonstrated by their contraction against a voluntary powerful sniff.[9]

The Cottle test is useful in evaluating static collapse of the nasal valve, but does not provide sufficient information for dynamic collapse. However, the Cottle test may be considered nonspecific owing to its false-positive and -negative rates, and the modified Cottle test is more effective and informative.[10] Although there is no significant valvular stenosis during nasal endoscopic examination, visualization of the rhythmic medial collapse of the nasal sidewalls differentiates dynamic valve collapse from static. Detection of a causative factor in nasal valve dysfunction may influence the success of treatment planning, and appropriate surgical and/or medical treatment approaches can be applied.[1,11]

Intrinsic and extrinsic nasal muscles are important for nasal breathing.[1] Because of the role of nasal muscles in respiration, during investigation of the causative factors in patients with internal nasal valve dysfunction, it is important to determine the state of the nasal muscles in addition to the cartilage and soft tissues. The activity of the nasal muscles can be measured by surface electromyography (EMG).[12] The present study was performed to evaluate nasal muscle function in patients with dynamic and static obstruction in the nasal valve region in comparison with the nasal muscle activity of normal healthy individuals. A surface EMG method was used to measure the nasal muscle activity of patients and healthy controls.

Materials and Methods

The study was conducted between April 2008 and January 2009 at the Otolaryngology Clinic, Haseki Training and Research Hospital, Istanbul, Turkey. After obtaining ethics committee approval, patients between the ages of 15 and 50 years who presented with difficulty in breathing through the nose were evaluated with a detailed history and otorhinolaryngologic examination by a specialist. To detect pathologies that may cause muscle disorders, we measured blood glucose, urea, sodium, potassium, calcium, creatinine, creatinine kinase, free thyroxine, and thyroid-stimulating hormone levels in all patients. Antinuclear antibody, antimitochondrial antibody, and antineutrophil cytoplasmic antibody levels were determined. Patients with a history of nasal surgery, acute or chronic sinusitis, nasal polyps, facial paralysis, or a known muscle disorder, and those currently using any medications were excluded from the study. Patients with normal neurological, muscular, physiological, and biochemical parameters in whom supra-alar collapse was observed during inspiration on otorhinolaryngology examination were included in the dynamic group. Twenty patients diagnosed with dynamic nasal valve pathology and 18 patients with single-sided static nasal valve stenosis, due to septum deviation, were included in the study. Twenty age-matched healthy volunteers without any difficulties in nasal breathing were selected as the control group. Detailed information about the procedures was provided, and informed consent forms were obtained from all patients and healthy volunteers.

Nasal muscle activities of all patients were measured by surface EMG, a noninvasive method, and the results were compared with measurements obtained in healthy volunteers. Nonfunctional status of the muscle without neurological or structural problems was defined as activity loss.

Surface EMG Measurement

The facial regions of all subjects were cleaned with a piece of cotton dampened with ether and alcohol and then dried before measurements were taken to prevent interference with recordings. The laboratory room temperature was set to 20°C and the skin temperature was set to 24°C. To confirm that the facial nerve was intact, we evaluated facial nerve motor responses by stimulating the nerve from the front of the stylomastoid foramen and then taking recordings from the facial muscles. Surface electrodes and reference electrodes were placed on the midpoint between the glabellum and the dorsal nasal bone. Active electrodes were placed on the related muscle at a distance of 2.54 cm from the reference. Recordings were taken first at rest and then at full contraction. Interference potentials were evaluated during full contraction, and spontaneous activity (denervation potentials) was evaluated at rest. EMG was performed bilaterally on five pairs of muscles (m orbicularis oris, m depressor septi, m dilator naris anterior, m nasalis transversalis, and m levator labii superioris alaque nasi) and the m procerus in all subjects (Fig 1).

EMG recordings of all subjects were evaluated by the same neuroelectrophysiologist. A Synergy 2004 model EMG device (Medelec Synergy N-EP—EMG/EP Monitoring Systems, VIASYS Healthcare, Madison, WI) was used for the analyses, with the lower filter set at 10 Hz and the upper filter set at 10 kHz. Recordings were made for each muscle as follows.

M orbicularis oris. To test the m orbicularis oris muscle, which is activated during a gentle smile, we placed the reference electrode at the lower point of the nasolabial

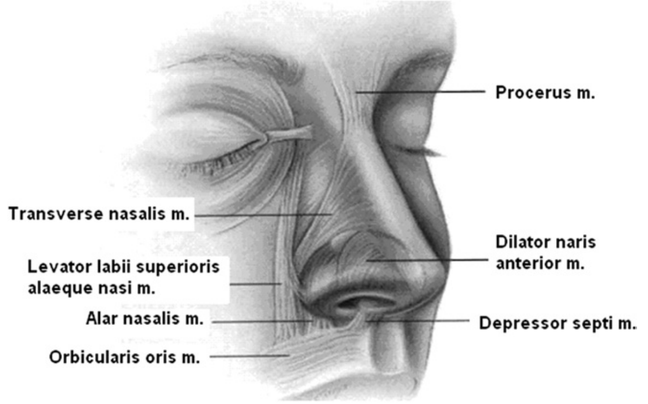

Figure 1 Nasal muscles evaluated by surface electromyography (courtesy of Jaye Schlesinger).

sulcus. The active electrode was placed at the midpoint of the upper lip, and the recordings were taken at rest and at full contraction.

M depressor septi. To test the activity of the m depressor septi muscle, which is activated during gentle downward motion of the upper lip, we placed the active electrode at the point of contact of the columella and the nasal skin. The reference electrode was placed at the point of the nasal tip. Recordings were taken at rest and at full contraction in a downward motion of the upper lip.

M dilator naris anterior. To test the m dilator naris anterior muscle, which is activated during nasal alar breathing, we placed the active electrode on the alar wing. The reference electrode was placed 2.54 cm above the alar wing.

M nasalis transversalis. To examine the activity of the m nasalis transversalis muscle, which is activated during strong nasal inspiration, we placed the active electrode on the rhinion region. The reference electrode was placed 2.54 cm below the rhinion region. Recordings were taken during rest and during strong nasal inspiration.

M procerus. To test the activity of the m procerus muscle, which is activated during full blinking and frowning, we placed the active electrode and the reference electrode 0.5 cm and 2 cm below the glabellum, respectively.

M levator labii superioris alaeque nasi. To examine the activity of the m levator labii superioris alaeque nasi muscle, which is activated during nose wrinkling, we placed the active electrode at the midpoint of the nasolabial sulcus. The reference electrode was placed 2.54 cm lateral to the nasolabial sulcus. Recordings were taken at rest and during nose wrinkling.

Statistical Analyses

Statistical analyses were performed with SPSS 16.0 for Windows (SPSS Inc., Chicago, IL), and P values < 0.05 were deemed to indicate statistical significance. The χ^2 test was used for comparison of qualitative variables between the groups. The Monte Carlo exact method was used to estimate the real χ^2 value when the null hypothesis of the χ^2 test was not fulfilled owing to small sample size. Student t test was used to compare the two groups when the numerical independent variables were normally distributed.

Results

The mean age of the 20 patients with dynamic nasal valve collapse (11 men, 9 women) was 33.0 $\pm$ 6.3 years. The mean age of the 18 patients with single-sided septum deviation and static nasal valve pathology (10 men, 8 women) was 27.2 $\pm$ 6.0 years. The mean age of the control group, which consisted of 13 men and seven women, was 30.1 $\pm$ 5.8 years. There was no significant difference between the patient and control groups in terms of age or sex.

No activity loss was noted in motor unit morphology or recruitment patterns (recruitment, amplitude, duration, and polyphasic pattern) in the EMG evaluations of right and left m orbicularis oris, m depressor septi, or m procerus muscles during inspiration and expiration in patients with dynamic nasal valve collapse and in the control group. Activity loss was observed during inspiration and expiration in the m levator labii superioris alaque nasi muscle in only one patient with dynamic nasal valve collapse, while no activity loss was noted in the m levator labii superioris alaeque nasi muscle within the control group. In the dynamic patient group, activity loss was observed during evaluation of the recruitment patterns and motor unit morphology (amplitude, duration, and polyphasic pattern) of the m dilator naris anterior muscle (right side, n = 7; left side, n = 9) and in the m nasalis transversalis muscle during inspiration and expiration (right side, n = 10; left side, n = 11). Normal findings were observed in all controls. The activity rates of the m dilator naris anterior and the m nasalis transversalis muscles were significantly different between the patient and control groups (m dilator naris anterior, right $P = 0.008$, left $P = 0.001$; m nasalis transversalis, right $P < 0.001$, left $P < 0.001$; Table 1).

Normal muscle activation was observed during expiration in all of 18 septum deviation patients with static nasal valve stenosis (Table 1). During inspiration, the m dilator naris anterior and m nasalis transversalis muscles failed to participate in breathing on the deviation side in 11 patients and bilaterally in four patients. Normal activity was observed during inspiration and expiration in three patients with septum deviation. No activity loss was observed in the motor unit morphology (amplitude, duration, and polyphasic pattern) or recruitment in the control group.

Discussion

Airflow through the nose is proportional to the radius of the airway raised to the fourth power, as described by Poiseuille's law. As air is inhaled through the nasal cavity, airflow accelerates as it enters the nasal valve. It follows that any small deflection of the nasal septum can lead to exponential effects on nasal airflow. As airflow increases through the valve, intraluminal pressure decreases, according to Bernoulli's principle. This drop in intraluminal pressure can cause collapse of an anatomically weakened lateral nasal wall. Any decrease in the structural integrity to the components of the nasal valve can lead to collapse and airway obstruction.[5]

Nasal valve dysfunction can result in a significant disease-specific decrease in quality of life. Relief of nasal obstruction due to nasal valve collapse is beneficial in improving the quality of life of these patients.[13] Surgical success is dependent on an accurate diagnosis, identifying the epicenter of pathology, and distinguishing between static and dynamic problems.[12,14] Determining the causative factor in nasal valve dysfunction is essential in planning goal-oriented treatment. Differential diagnosis should be based on detailed examination. However, in most cases the problem is multifactorial.[1,5]

Table 1
Results for the patients with dynamic and static nasal valve failure and for the control group

Investigated muscle	Loss of activity, n (%) Dynamic (n = 20)	Static (n = 18)	Control (n = 20)	*P* value
M dilator naris anterior				
Right	7 (35)	0 (0)	0 (0)	0.008
Left	9 (45)	0 (0)	0 (0)	0.001
M nasalis transversalis				
Right	10 (50)	0 (0)	0 (0)	<0.001
Left	11 (55)	0 (0)	0 (0)	<0.001
M levator labii superioris alaeque nasi				
Right	1 (5)	0 (0)	0 (0)	1.000
Left	1 (5)	0 (0)	0 (0)	1.000
M depressor septi				
Right	0 (0)	0 (0)	0 (0)	
Left	0 (0)	0 (0)	0 (0)	
M orbicularis oris				
Right	0 (0)	0 (0)	0 (0)	
Left	0 (0)	0 (0)	0 (0)	
M procerus				
	0 (0)	0 (0)	0 (0)	

It is important to determine whether the nasal valve pathology has a static or dynamic etiology. For this purpose, surface EMG can be used as a noninvasive method to measure the activities of the nasal muscles.[11,15]

The activity of the nasal muscles varies among individuals, and subjects with active nasal muscles are able to control their nasal valve function.[15] Kienstra et al[3] reported that resting nasal muscle tension, which opens the nasal airway, plays an important role in increasing nasal airflow. EMG studies in volunteers without any nasal complaints indicated that the m dilator naris, m nasalis, and m apicis nasi muscles are strongly associated with breathing and that these muscles could prevent nasal valve collapse.[12] Kienstra et al paralyzed the nasal muscles of volunteers with an injection of lidocaine to examine their effects on nasal airflow. Rhinomanometric measurements were performed at rest and during muscle activity before and after paralysis. The results indicated that the nasal muscles contributed to airflow at rest and during activity.[3] External rhinoplasty surgery can impair nasal muscle activity owing to detrimental effects on the muscular attachments.[16]

In all 18 patients with static wall stenosis, normal muscular activity was measured by EMG during expiration. Of these, 11 had unilateral muscular abnormalities and four had bilateral muscular abnormalities during inspiration attributed to mechanical effects of septal deviation. Normal muscular EMG findings during expiration in all muscles tested demonstrated the absence of muscular dysfunction in these patients with static nasal valve obstruction. That is, some nasal muscles that do not participate in inspiration play a role during expiration in patients with unilateral septum deviation. These observations suggest that these muscles do not participate in inspiration owing to nasal airway obstruction.

As the contraction forces of muscles act on the longitudinal axis from the origin to the insertion points, weakness in the supporting tissues at muscle attachment points may preclude the muscle from participating in motion when it has to perform its function, especially during deep inspiration. This hypothesis was also supported by the lack of atrophy, which might lead to a significant asymmetry, despite the inability to detect any activity in these muscles, the lack of spontaneous activity on EMG, and no apparent change in motor unit morphology.

No dysfunction was detected by EMG in any of the muscles of the eight (40%) subjects in the dynamic patient group. In patients included in the study owing to the absence of any static agent, no muscle dysfunction that could explain the dynamic internal nasal valve collapse was detected, which may indicate cartilaginous weakness or abnormality in etiology. Strengthening of the cartilaginous structures controlling the valve mechanism and anterior region of the valve would be beneficial for preventing dynamic pathologic collapse.

Nasal muscle function is adjusted in the treatment of respiratory disorders related to the nasal valve. In studies conducted in patients with dynamic nasal valve pathology, Vaiman et al[10,17] performed transcutaneous and intranasal muscle electrostimulation, biofeedback exercises specific for nasal muscles, home exercises, surface and intranasal surface EMG-assisted specific nasal muscle education to treat nasal muscle dysfunction; they reported a success rate of 58 percent to 80 percent.

Surgical options for the treatment of obstruction due to static nasal valve failure include septoplasty, spreader graft, flaring suture, and butterfly grafts, while dynamic nasal valve pathologies can be treated by batten graft, overlay graft, nasal valve suspension suture, and alar rim reconstruction. This study demonstrated that the activity loss in nasal muscles in patients with dynamic nasal valve collapse could be detected by EMG. During planning of the treatment of patients with dynamic and static internal nasal valve pathology, the cartilaginous skeleton should be supported more efficiently in patients with dynamic valve failure, because the functional loss of nasal muscles occurs in addition to other nasal pathology.

The roles of muscular activity in the nasal airway have been demonstrated previously by various methods.[3,12] In the present study, surface EMG was used to detect functional abnormalities in the nasal muscles of patients with dynamic and static nasal valve failure. Thus, the present study contributes to the diagnosis and treatment of such patients. The results of this study indicated that some of the muscles did not contribute to respiration during inspiration and expiration in the dynamic patient group. While normal activity was observed in all muscles during expiration in the static group, muscles that did not contribute to respiration were determined at the septal deviation side during inspiration. However, normal nasal muscle activity was observed during inspiration and expiration in the control group.

In conclusion, the status of nasal muscles should be taken into account by clinicians treating patients with nasal airway obstruction. While morphological impairment is present in the cartilaginous structure in static nasal valve stenosis, functional abnormalities are likely present in the cartilaginous or muscular structure in dynamic nasal valve collapse. The role of nasal muscles in nasal valve pathologies should be considered and treatment targeting muscular activity disorders detected by EMG should be adopted for more effective results.

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Author Contributions

Fadlullah Aksoy, data analysis and interpretation; **Bayram Veyseller,** drafting of article or revising it critically for important intellectual content, data analysis and interpretation; **Yavuz Selim Yıldırım,** data acquisition; **Hürtan Acar,** data acquisition; **Hasan Demirhan,** data analysis and interpretation; **Orhan Özturan,** critical revision of article for important intellectual content, data analysis and interpretation.

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