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Intranasal electromyography in evaluation of the nasal valve*

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SUMMARY

Objectives: *The present study was performed to investigate the best way of using surface electromyography (sEMG) in evaluation of muscle involvement in nasal valve function. The function of the nasal muscles in nasal valve movements has not been investigated sufficiently and in the present study we tried to improve the way of testing these muscles introducing the intranasal placement of surface EMG electrodes.*

Methods: *Skin surface electromyography (EMG) and intranasal electrode EMG investigation of nasal muscles was performed in two groups (n=30 for each Group) of healthy subjects: (1) subjects with extremely effective coordination of nasal muscles and (2) those with extremely poor coordination of nasal muscles. Functions of the nasal muscles were assessed by EMG in response to breathing and voluntary nasal movements.*

Results: *In both Groups, during normal breathing all the tested muscles were not active. During forced nasal inspiration in Group 1 the transverse nasalis, anomalous nasi, alar nasalis and dilator naris anterior were active. In Group 2 during forced nasal inspiration these muscles remained inactive. During rhythmic widening of the nostril, the tested nasal muscles were active in subjects of Group 1 and significantly less active in Group 2 ($p=0.0024$). In both Groups the amplitude of muscle activity, recorded from intranasal electrodes was significantly higher that the amplitude recorded from the skin electrodes ($p<0.05$). During the tests with two intranasal electrodes, the insignificant difference was detected in amplitude between left and right nostrils in majority of subjects (Group 1 $p=0.15$; Group 2 $p=0.1$).*

Conclusion: *We conclude that in human population the ability to operate nasal muscles is varying from person to person, i.e. the nasal muscles can be either inactive ("relatively rudimentary") or active. This fact should be taken into account before any surgical intervention is planned. The subjects with active nasal muscles can control the function of their nasal valve. The intranasal surface EMG is a more direct and precise EMG method for nasal valve evaluation in comparison to skin surface EMG testing.*

Key words: electromyography, normal subjects, nasal valve

INTRODUCTION

The nasal valve, or the nasal valve angle, is the narrowest portion of the nasal cavity. This junction between the nasal septum and the caudal upper lateral cartilage widens and narrows under the influence of the nasal musculature during respiration. When negative inspiratory pressures are generated during nasal breathing, the nasal valve narrows, thereby increasing the nasal resistance and slowing the velocity of the airstream (Bridger, 1970). If the nasal valve is narrowed by deformities of the adjoining nasal septum, it is predisposed to collapse prematurely, resulting in symptoms of nasal blockage. In addition to septal deviations, nasal valve stenosis or nasal valve collapse can be observed as a result of common colds, hay fever, acute or chronic sinusitis, nasal allergy, aggressive resection of alar cartilage during rhinoplasty, scarring from burns or trauma, Bell's palsy, stroke, and senile atrophic changes of upper and lower cartilages and nasal muscles. Even minor changes in the shape or cross-sectional area of the nasal valve may produce clinical symptoms of nasal obstruction.

While the above mentioned etiology includes both anatomical and physiological changes, the nasal valve can be compromised either anatomically (stenosis) or physiologically (collapse). In case of collapse the role of the muscles of the nose is very important and should be evaluated very carefully. As it

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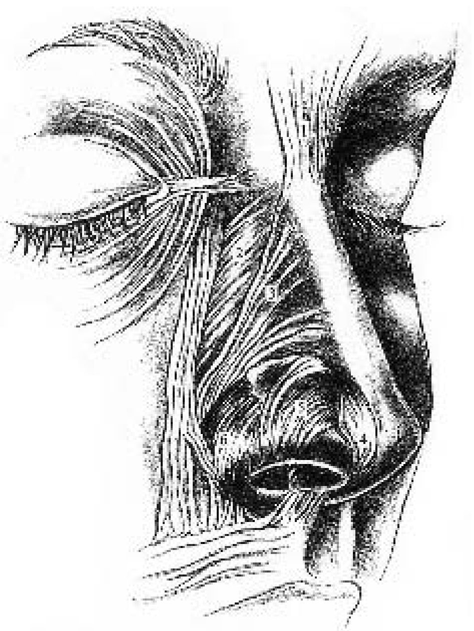


Figure 1. Nasal muscles. 1. m. Procerus; 2. Anomalous nasi m.; 3. Transverse nasalis m.; 4. Compressor narium minor m.; 5. Dilator narium anterior m.; 6. Alar nasalis m.; 7. Depressor septi nasi m.

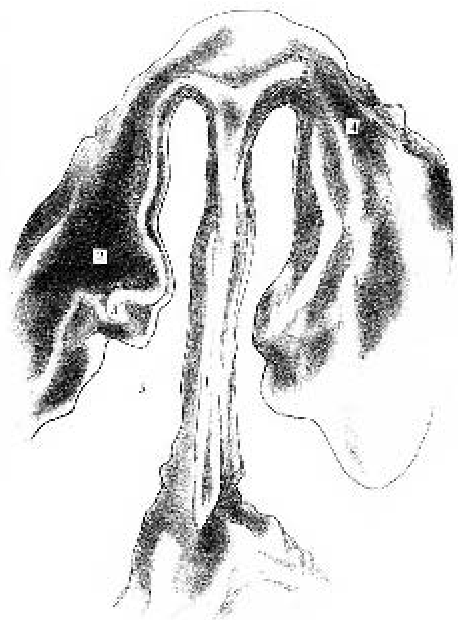


Figure 2. Frontal section of the nasal valve seen from in front (cadaver). 1. Septal cartilage; 2. Anomalous nasi m.; 3. Greater alar cartilage (up from "3") and lower edge of lateral nasal cartilage (down from "3"); 4. Transverse nasalis m.; 5. Nares.

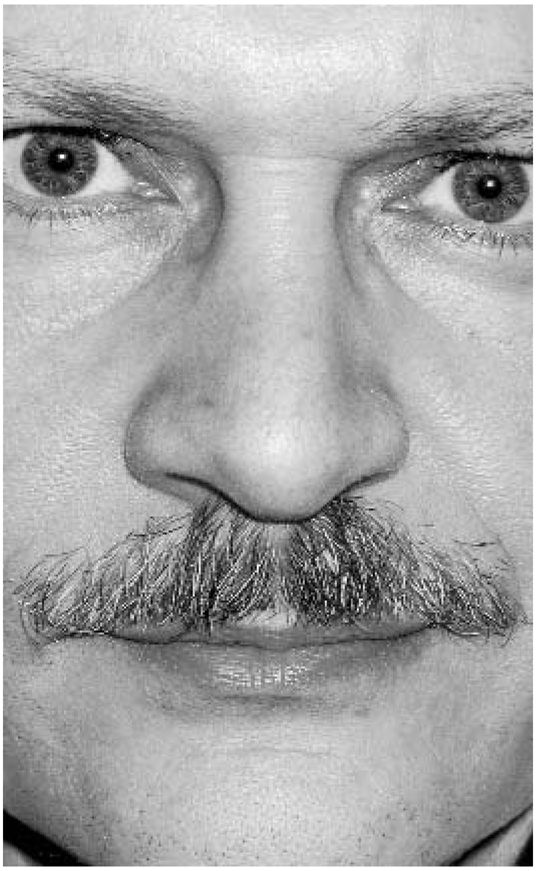
was previously investigated (Haight et al., 1983), when the alar muscles were paralized by lidocaine block of the VIIth nerve, alar collapse occurred. In the natural way, the same can be observed after a stroke or as a result of the Bell's palsy.

Since the nasal muscles have been described in the classic "Anatomy of the Human Body" by Henry Gray (1825-1861) (Gray, 2000 (1918)), later works not only used different terminology for these muscles but also ignored some, creating confusion. Frequently these muscles are referred to as "rudimentary" (Rubinstein, 1977; Verhaegen, 1985; Evans, 1992; Hoeybergs et al., 1996) to confuse practitioners even more, while other works state that the functions of these muscles are very far from rudimentary (Asakura et al., 1990; Rohrich et al., 2000). Gray described five nasal muscles: Procerus (*Pyramidalis nasi*), covering the lower part of the nasal bone and responsible for characteristic transverse wrinkles at the root of the nose; Nasalis (*Compressor nasi*), divided into a transverse part, covering the dorsum of the nose as well as the upper lateral cartilages and responsible for stability of the lateral nasal wall, and an alar part, covering the greater alar cartilage and helping to open the nostrils; Depressor septi (*Depressor alae nasi*), inserted into the septum and the columella, and possibly attributing to widening the nostril; and Dilatators (sometimes referred to as dilators) naris posterior and anterior, covering alar cartilage and inserting into the skin of the nasolabial groove, which dilate the anterior segment of the nares. Confusion arises when Dilatator naris posterior is called "pars alaris musculi nasalis" (Nolst Trenité, 1998) or "muscle of the nasal tip" (Lang, 1989).

In addition to that, the small compressor narium minor muscles (sometimes called as apical nasal muscle or *apicis nasi* in Latin) cover the apical area of the alar cartilage from both sides, *anomalous nasi* muscles run beneath transverse nasalis muscle, and *levator labii superior alaeque nasi* muscles are attached to the perichondrial layer of the lower lateral cartilage and originates in the frontal process of the maxillary bone. The *levator labii* also helps to dilate the nostrils (Figures 1 and 2).

Since the works of Griesman (1944) and Leturneau and Daniel (1988), it has been generally accepted, that all these numerous small muscles can be functionally subdivided into elevators (procerus, levator labii superioris alaquae nasi, anomalous nasi), *depressors* (the alar part of m. nasalis, dilator naris posterior, depressor septi), *dilators* (dilator naris anterior), and *compressors* (transverse part of m. nasalis, compressor narium minor). The elevators shorten the nose and dilate the nostrils, the depressors lengthen the nose and dilate the nostrils, the dilator dilates the nostrils, and the compressors lengthen the nose and narrow the nostrils. This classification, however, was developed from the plastic surgery viewpoint and does not take into account rhinologic problems. For example, it does not exactly correspond to the function of the nasal valve, and it is not yet clear how the concord movements of the above described muscles affect the function of the nasal valve.

The present study was performed to investigate the best way of using surface electromyography (sEMG) in evaluation of muscle involvement in nasal valve function. Recent studies (Thumfart et al., 1983; Stenge et al., 1994; Ozturan et al., 2001) proved the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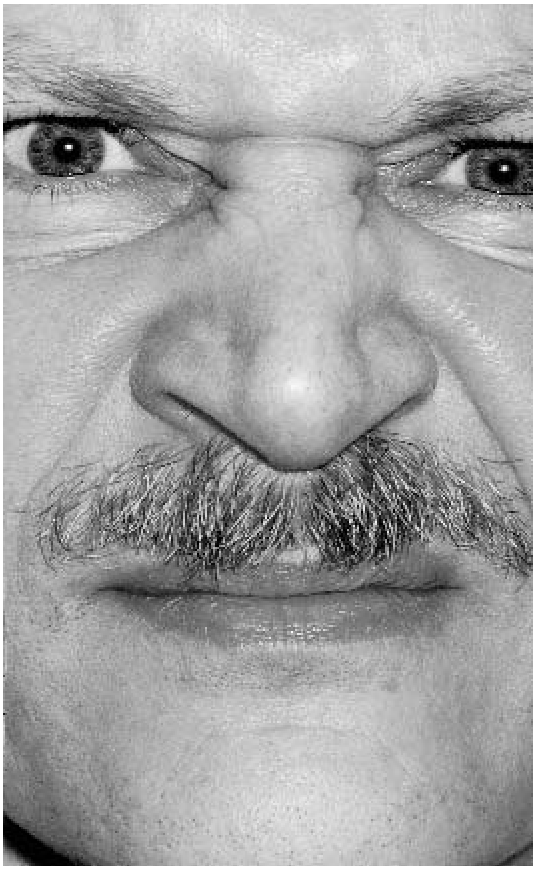
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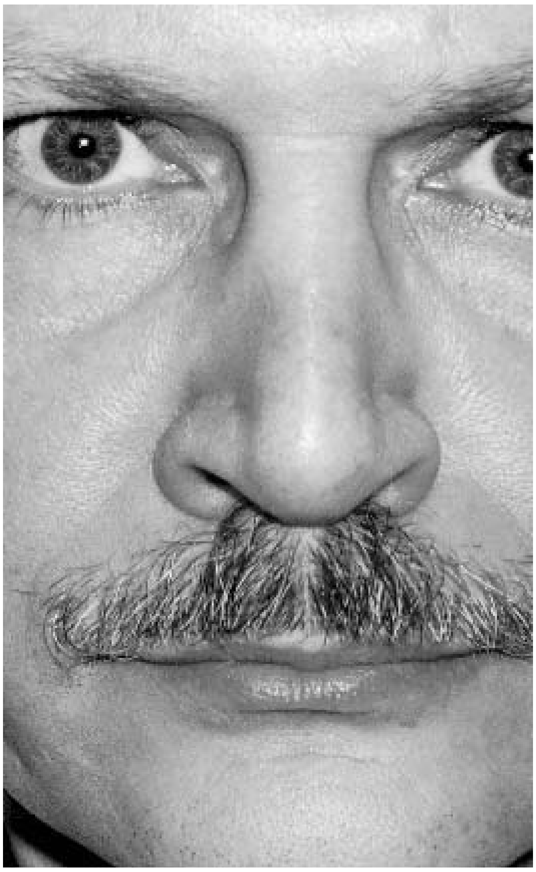
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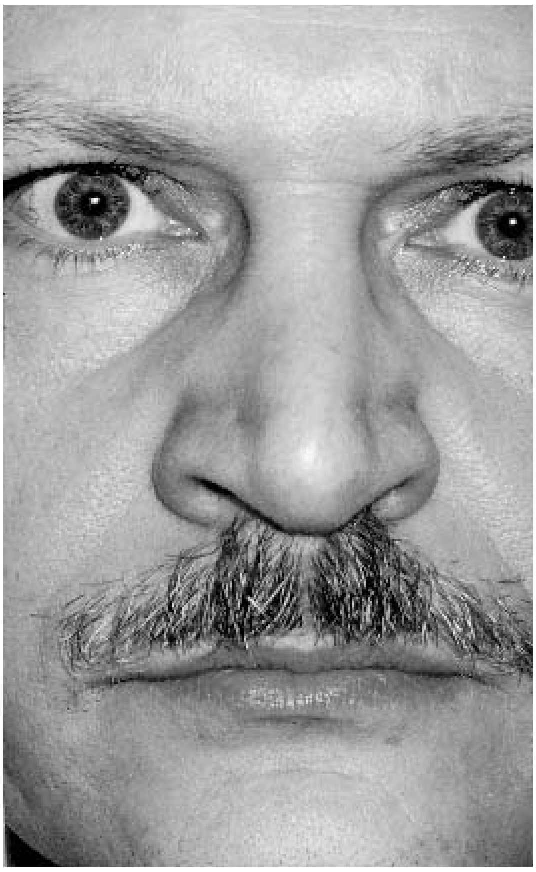
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Figure 3. The movements of the nose during selecting muscle tests. A. normal position of the nose; B. shortening the nose C. lengthening the nose E. dilation of the nostrils.

importance of EMG tests in rhinology. It was also hypothesized that mm. *Dilatator nasi*, *nasalis*, and *apicis nasi* probably contribute to the prevention of collapse of the nasal valve (Bruintjes et al., 1996). These studies, however, did not take into account the fact that different people operate their nasal muscles more or less effective. This problem does not exist in EMG studies of, for example, muscles of the hand, but it is of paramount importance when the nasal muscles are investigated. In reality, there are people who can voluntary operate their nasal muscles and there are people who do not, exactly like the people who can and who cannot move their ears. The function of the nasal muscles in nasal valve movements also has not been investigated sufficiently and in the present study we tried to improve the way of testing these muscles introducing the intranasal placement of surface EMG electrodes.

MATERIALS AND METHODS

Subjects

The volunteers were recruited across a 3-month period. The study was approved by the Medical Center Ethics Committee (outpatient department). The subject group included 60 adults, 32 women and 28 men, ranging in age from 18 to 60 years (mean = 28,4 years). Before the study, all subjects completed a questionnaire regarding their general health and their medical history. Subjects had no history of medical problems or medications that might affect breathing and/or facial muscles. All subjects had normal nasal anatomical structures. None of them had a history of rhinoplasty, septoplasty or other similar surgery. All subjects were examined by ENT physicians prior to their participation to the study.

These 60 subjects were selected from approximately 220 volunteers on the criterion of their abilities to operate muscles of the nose. Using this criterion, the subjects were selected into two groups: Group 1 (n=30) – the subjects who can fully control and operate their nasal muscles (effective coordination of nasal muscles); Group 2 (n=30) – the subjects who cannot operate their nasal muscles at all or operate them very poorly (poor coordination of nasal muscles). The volunteers were asked to perform three tasks (Figure 3):

1. To shorten the nose; instruction given to a volunteer: “Wrinkle your nose without knitting your brows. Do not make a complete wry face, just wrinkle your nose.” This test helps to evaluate mm. the procerus, the levator labii superior alaeque nasi, the anomalous nasi and, to some extend, the transverse nasalis.
2. To lengthen the nose; instruction given to a volunteer: “Move your nostrils down without knitting your brows or moving your lips and chin.” This test helps to evaluate mm. nasalis (both parts), the depressor septi and the compressor narium minor.
3. To narrow the nostrils; instruction given to a volunteer: “Try to dilate your nostrils without making a wry face”. This test helps to evaluate the alar portion of the nasalis muscle and the dilator naris anterior.

After these tests were performed by all the volunteers (220), we selected 30 subjects with the best results in all three tests into Group 1, and 30 subjects with the poorest results into Group 2. The subjects chosen to Group 1 performed all three tests easily and with good muscle coordination. The subjects in Group 2 were unable to perform tests 2 and 3 and performed test 1 with bad muscle coordination involving additional face muscles. There were no subjects who were unable to perform test 1 at all.

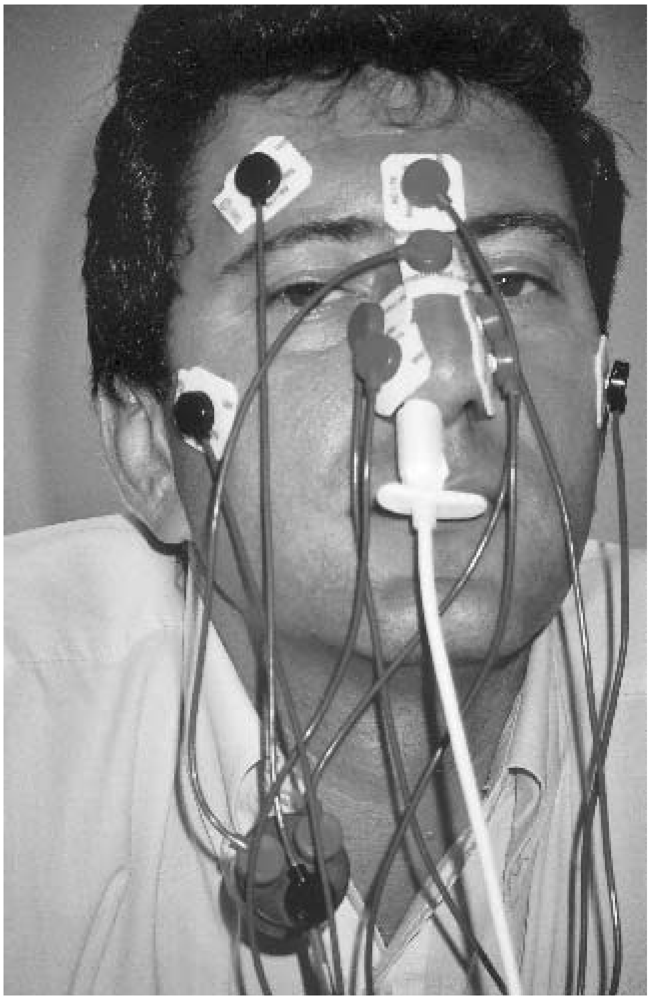

Figure 4. Placement of three pairs of external surface EMG electrodes and an intranasal EMG sensor, used at the study.

Electromyographic techniques

We used two types of surface EMG recordings: extranasal (Figure 4) and intranasal (Figure 5). All external EMG recordings were made using standard surface sensors (AE-178). (Electrode material: silver coated; shape: discs; size: diameter 11 mm; the interelectrode distance: 20 mm). The equipment used for the sEMG recordings was a NeuroDyne Neuromuscular Sys/3 four-channel computer-based EMG unit

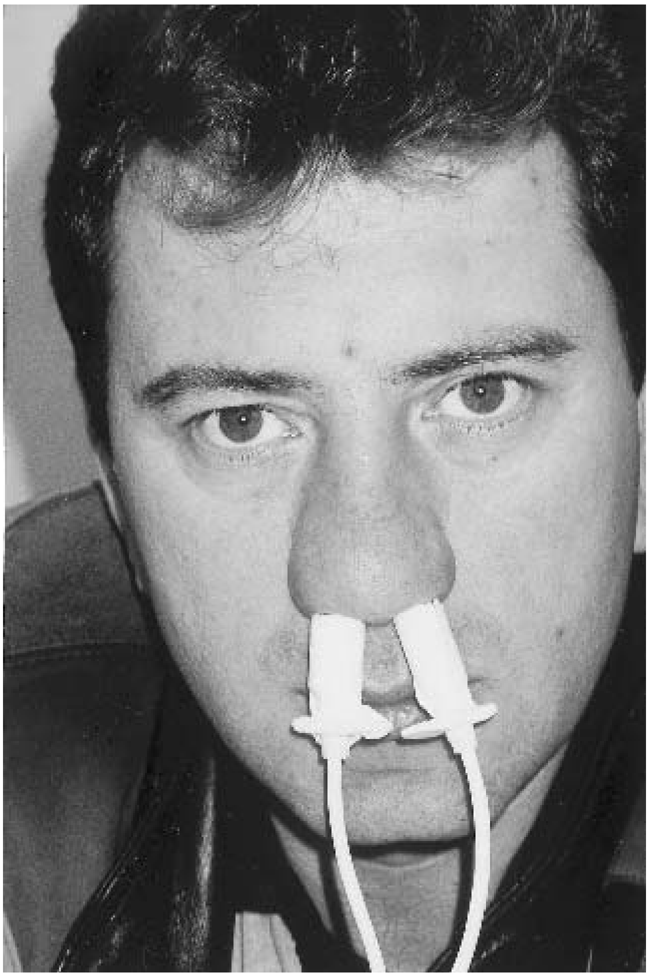

Figure 5. A subject with two intranasal EMG sensors, as used in the study.

with NeuroDyne Medical software (NeuroDyne, Cambridge, MA, USA) and AE-204 active sensors attached to AE-178 electrodes. The unit has a wide bandpass filter, a bandwidth (RMS) of 25-450 Hz and a 60Hz notch filter. The system uses an active electrode consisting of a compact sensor assembly that includes a miniaturized instrument preamplifier. Locating the amplifier at the electrode site allows cancellation of artifacts and boosting of the signal before it is transferred down the electrode cable. The integration period of the sEMG signal at the hardware level is 25 milliseconds. This has very little effect on the shape of the signal. For the software, the underlying sampling speed is 100 Hz (i.e., 100 samples per second). The recordings of this high-speed sampling are then averaged, based on the selected sampling rate. Each sEMG recording is full-wave rectified and low-passed filtered. The computer program indicates the mean, standard deviation, minimum, maximum, and range of muscle activity during each trial, as well as its duration. Muscle activity (EMG) is quantified in microvolts (ÌV).

For intranasal surface EMG investigation we invented an intranasal EMG sensor. This sensor (Figures 6 and 7) is a tube which has an oblong shape designed to fill the nasal vestibule up to the nasal valve. It has two active and one ground electrode and a wide breathing hole in a center. The diameter goes in small (10 mm), medium (12 mm) and large (14 mm) sizes. To achieve better electrode contact and to prevent mucosa from scratching, the intranasal sensor should be used with an electrode gel suitable for contact with mucosa (highly conductive multi-purpose electrolyte "Signa-gel" electrode gel, Parker Labs, Inc., New Jersey, or similar). Like, for example, the perineometer EMG sensor of John D. Perry, Ph.D., Behavioral Medicine Institute, Philadelphia, our intranasal sensor also connected with the surface EMG device through the IA-250 EMG Amplifier (NeuroDyne Medical Corp., USA) that contains special line integrity monitoring circuitry, an EMG preamplifier and active noise cancellation circuitry.

Each EMG record was full-wave rectified and low-passed filtered. The computer program indicates mean, standard deviation, minimum, maximum, range of muscle activity during each trial, and its duration. Muscle activity (EMG) is quantified in microvolts.

Three pairs of stick-on disposable bipolar surface electrodes were used for external recording. Electrical impedance at sites of electrode contact was reduced, as target areas were lightly scrubbed with alcohol gauze pads, followed by application of an electrode gel. Each pair of electrodes was placed on the nasal skin in such a way that they selectively recorded the

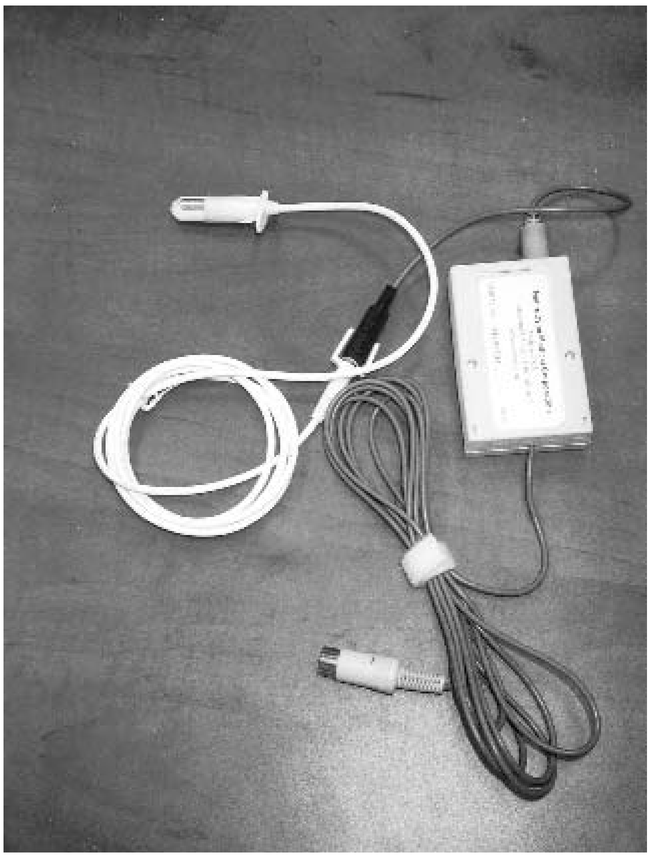

Figure 6. An intranasal surface EMG sensor.

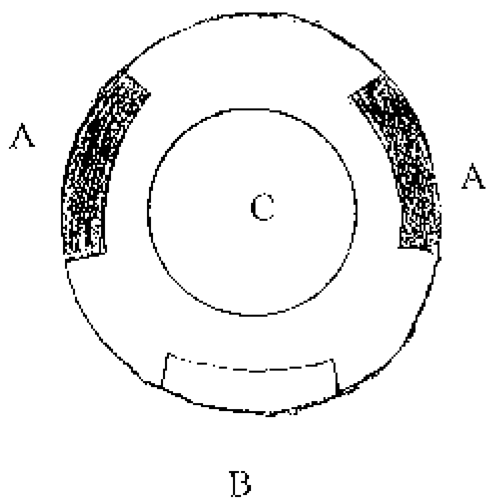

Figure 7. Cross-section of the intranasal surface EMG sensor. A – active electrodes, B – ground electrode, C – breathing hole.

activity of these muscles. The electrode placement was as follows (Figure 4): the upper pair above the procerus; the middle pair above the transverse nasalis and anomalous nasi; and the lower pair above the alar nasalis and dilator naris anterior. The intranasal electrode sensor takes information from the depressor septi, alar nasalis and dilator naris anterior. For better results, the intranasal sensor should be placed close to supra-alar crease. There is a space in the soft-tissue covering of the nose between upper lateral and lower lateral (alar) cartilages where electric signals from the muscles are the highest.

Procedures

After electrode placement, each participant performed two sets of three tasks:

1 normal nasal breathing (15 sec); instruction given to a volunteer: “Breathe normally”;
2. forced nasal inspiration (15 sec); instruction given to a volunteer: “Breathe as deep as you can but in normal pace”;
3. rhythmic widening of the nostril; instruction given to a volunteer: “Try to move your nostrils to make them wider”.

For the second set of the same tasks, the external surface electrodes were removed and subjects performed the tests with two intranasal electrodes gently inserted (Figure 5).

Statistics

Because of the non-homogeneity of the recorded variances and asymmetric distribution of evaluating data, a nonparametric “Sign test” in paired groups was performed (with $n=30$ and $p=0.05$) (Bland, 2000). Two groups were statistically compared by one-dimensional analysis of variance, SPSS Standard version 10.0.5 (Chicago, IL, 1999). The dimension evaluated was voltage data from the intranasal sensor, the confidence interval was 95%, and the level of significance was set at $p<0.01$.

RESULTS

In both Groups, during normal breathing all the tested muscles were not active. During forced nasal inspiration in Group 1 the transverse nasalis, anomalous nasi, alar nasalis and dilator naris anterior were active. In Group 2 during forced nasal inspiration these muscles remained inactive, i.e. deep breathing was achieved with additional involvement of the chest muscles only. During rhythmic widening of the nostril, the transverse nasalis, the depressor septi, alar nasalis and dilator naris anterior were active in subjects of Group 1 and significantly less active in Group 2 ($p=0.0024$) (Figures 8 and 9).

In both Groups the amplitude of muscle activity, recorded from intranasal electrodes was significantly higher that the amplitude recorded from the skin electrodes ($p<0.01$). During the tests with two intranasal electrodes, an insignificant difference was detected in amplitude between left and right nostrils in the majority of subjects (for Group 1 $p=0.15$; for Group 2 $p=0.1$). This left-right difference became more expressive during the forced breathing test, but remaining statistically insignificant (Group 1: $p=0.026$; Group 2: $p=0.04$). There was no statistical difference between male and female subjects in these studies.

DISCUSSION

With an increasing trend towards a more evidence-based style of medical practice, it is highly likely that there will be an increased demand for objective methods to assess the nasal functions in routine ENT practice. The methods of objective airway testing like acoustic rhinometry or rhinomanometry do not specifically evaluate physiological conditions of muscles responsible for functions of the nasal valve (Pallanch, 1998). Limitations of rhinomanometry and of acoustic rhinometry are well described (Quine and Eccles, 1999; Cakmak et al., 2001). Surface EMG thus remains a valuable method to test the activity of muscles that affect physiology of the nasal valve. While the plastic surgery approach deals with all the muscles of the nose in their response to surgical intervention, an otolaryngologist who wants to investigate the nasal valve before surgical treatment, should concentrate on several specific muscles.

Surface EMG evaluation of nasal muscles has several limitations. Reported studies in normal subjects show a very wide range of normal amplitudes for sEMG studies. These variations are not only due to biologic causes but also are greatly affected by such technical factors as skin/electrode impedance, depth of the muscle from the skin surface, location of the recording electrodes in relation to anatomic structures, variation in muscle size among individuals, and temperature. The magnitude of the absolute value of EMG activity within subject, when electrodes have been removed and replaced, is difficult to compare. Intranasal sensor helps to reduce an influence of some of these shortcomings. The sensor fits completely to the nasal vestibule (it comes in three sizes), it can be removed and replaced taking the same place.

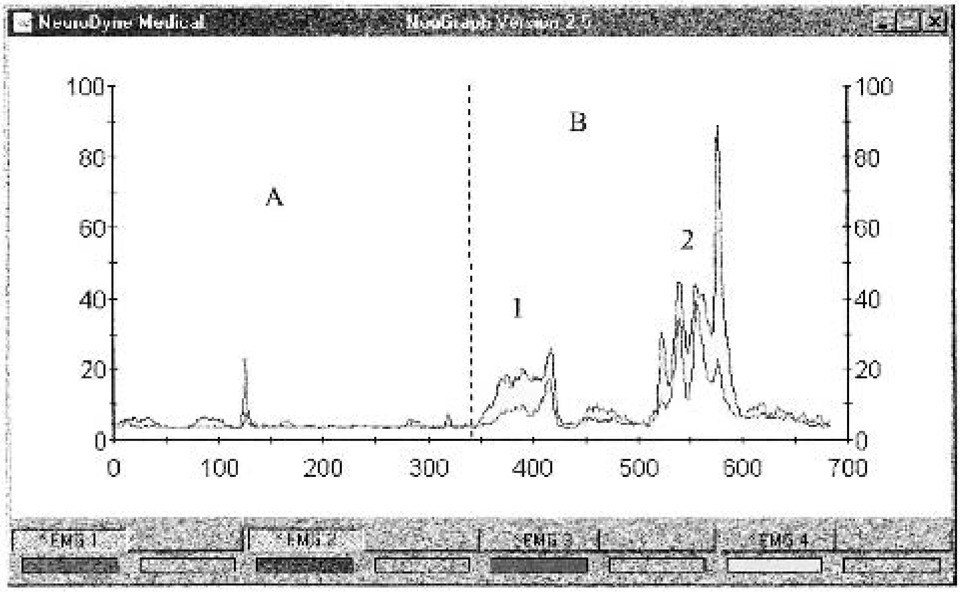

Figure 8. EMG record of normal breathing and widening of the nostrils in a subject with well controlled muscle of the nose (Group 1). A – normal breathing, B – forced (deep) breathing, 1,2 - inhales. Upper line – intranasal location, lower line – external skin location (m. nasalis). Other locations eliminated for clearer demonstration.

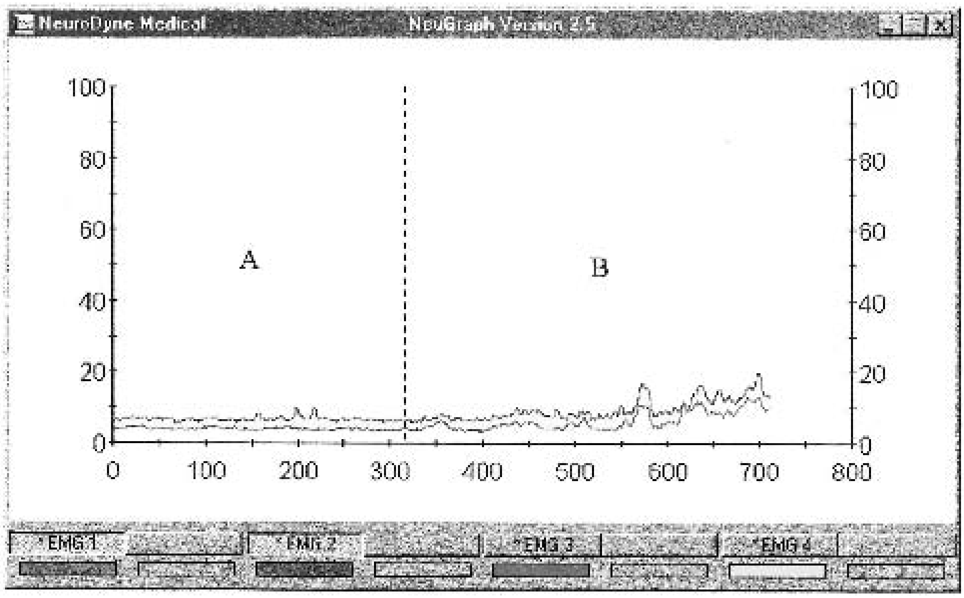

Figure 9. Normal breathing and widening of the nostrils in a subject with poor controlled muscle of the nose (Group 2). A – normal breathing, B – forced (deep) breathing. Upper line – intranasal location, lower line – external skin location (m. nasalis).

It is because of the wide variation in the normal values that absolute value of the amplitude of muscle activity is considered less clinical useful. The EMG amplitude, however, remains an important aspect in the relationship between muscle force and the associated electric activity (Isley et al, 1993). There is no simple relationship between the sEMG signal and muscle force. However, it can be empirically shown that the amplitude of the EMG signal generally increases with isometric muscle force. Based on this property, the sEMG amplitude can be used to estimate muscle force during contractions of nasal muscles involved in breathing. When all the different types of neuromuscular disorders are considered collectively, amplitudes are by far the most informative (Wilbourn and Ferrante, 2000). Regarding neurogenic lesions like Bell's palsy or stroke, some authors argue, amplitudes are the only components that have a direct relationship to clinical symptoms (muscle weakness) (Wilbourne, 2002). In our study, we found a clear difference in amplitude measurements between the group with active nasal muscles and the group with inactive nasal muscles.

It is clear that the procerus, the anomalous nasi, and the transverse part of the m. nasalis do not affect the function of the nasal valve because they are located above the nasal bone part and the upper lateral cartilage. At the same time, the dilator naris anterior and the alar part of the m. nasalis are very active in nasal valve regulation in case if they are developed well. The direct influence of the depressor septi and the levator labii superioris alaquae nasi on the nasal valve is not yet clear.

We feel that the combined testing of the dilator naris anterior and the alar part of the m. nasalis by external and intranasal surface EMG can benefit to better understanding of real electric activities of these muscles, i.e. to better understanding of the nasal valve physiology.

The intranasal sensor is a simple and non-expensive device, well compatible with existing IA-250 EMG amplifier and surface EMG devices. We found it well fit for both screening procedures and more serious diagnostic processes. When the two intranasal sensors are inserted, they can serve for quick objectivisation of left-right nostril differences in cases of stroke, Bell's palsy, septal deformity and similar diseases.

The EMG data generated in our study correlated quite well with the visual impression of nasal muscle activity. Apparently, subjects with intermediate muscle function have intermediate muscle control. It does not mean that people with strong muscle function are less susceptible to nasal valve dysfunction. Many of the etiological causes of nasal obstruction indicated in the introduction do not affect nasal muscles directly. However, we believe that patients could be trained to improve their nasal muscle function with exercises. Currently we are involved in a study of EMG biofeedback training to improve the airway in patients with nasal valve dysfunction and to avoid surgical intervention. While our current study was performed on healthy volunteers, we see its certain clinical relevance as a database for future studies on patients. Indeed, are patients with poor muscle function less likely to benefit from septoplasty and/or turbinate surgery? Another direction of further studies is to test whether patients with poor nasal muscle function are more likely to complain of nasal obstruction. Intranasal and surface EMG remains a valuable tool for these future studies.

CONCLUSION

We conclude that in the human population the ability to operate nasal muscles is varying from person to person, i.e. the nasal muscles can be either inactive ("rudimentary") or active. This fact should be taken into account before any surgical intervention is planned. The subjects with effective coordination of nasal muscles can control the function of their nasal valve. The intranasal surface EMG is a more direct and precise EMG method for nasal valve evaluation in comparison to skin surface EMG testing. The method in quick, simple, direct, and with a low level of discomfort of the examination.

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