Rhinology, 42, 145-152, 2004

# Muscle-building therapy in treatment of nasal valve collapse*

Michael Vaiman, Ephraim Eviatar, Samuel Segal

Department of Otolaryngology, Assaf Harofeh Medical Center, Affiliated to Sackler Faculty of Medicine, Tel Aviv University, Israel

SUMMARY

***Objectives:*** *The purpose of this paper is to describe the outcome of muscle-building therapy for nasal muscles in cases of nasal valve stenosis or collapse. The present study was performed to investigate the best way to combine transcutaneous and intranasal surface electromyography (sEMG) biofeedback training of muscles involved in nasal valve function with a home exercise program and electric stimulation of nasal muscles.*

***Methods:*** *A randomized pilot study of 3 groups of patients (n1=12, n2=12, n3=10; total 34 patients) presenting with symptoms of obstructed nasal breathing was conducted. All selected patients demonstrated nasal valve stenosis with a positive Cottler maneuver and clinically evident nasal valve collapse. Follow-up ranged from 8 to 12 months. Treatment for Group 1 included transcutaneous and intranasal electric stimulation of nasal muscles only. Treatment for Group 2 included biofeedback training and home exercise program of specific nasal movements, and treatment for Group 3 included surface and intranasal EMG biofeedback assisted specific strategies for nasal muscle education, home exercises and electric stimulation.*

***Results:*** *All patients in these groups exhibited subjective improvement. For Group 3, in 80% the improvement was proved objectively; for Group 2, in 75% the improvement was proved objectively; for Group 1, in 58,33% the improvement was proved objectively. We found no significant difference between the results in Groups 3 and 2 and poorer results in Group 1.*

***Conclusion:*** *Relieve of nasal valve stenosis and collapse can be achieved with a complex muscle-building therapy as described. It helps a significant cohort of patients with symptoms of obstructed nasal breathing to avoid surgical intervention. Electric stimulation of the muscles does not contribute significantly in achieving of good results.*

*Key words: nasal valve stenosis, EMG biofeedback treatment, electric stimulation*

## INTRODUCTION

It was well understood recently that quality of life of patients with nasal obstruction is significantly affected. Symptoms like nasal obstruction and congestion, which usually are described by patients as difficulties of nasal breathing associated with unpleasant sense of fullness or heaviness in the nose, may result in different outcomes from chronic mouth breath to a need for endonasal operation. Evaluating patients with nasoseptal deformities, scarring from burns or trauma, Bell's palsy, senile atrophic changes of upper and lower cartilages and nasal muscles and other disorders that can affect the nasal valve, a surgeon may suggest septorhinoplasty, implants or suspension sutures to relieve obstructed nasal breathing. Even after the operation quality of life assessment of these patients might show insignificant improvement (Rhee et al., 2003). Operation of nasal valve plasty might have insufficient results.

The nasal obstruction pathology includes both anatomical and physiological changes. It means that the nasal valve can be compromised either anatomically (stenosis) or physiologically (collapse), or by stenosis+collapse combined. The nasal valve controls the inspired air currents, changing them from a column to a sheet of air and giving them both resistance and velocity, producing greater depth of respiration. In case of its collapse the role of the muscles of the nose is very important and should be evaluated carefully. If the nasal valve is narrowed by weakness of these muscles, it is predisposed to collapse prematurely, resulting in symptoms of nasal blockage (Haight et al., 1983). While rigid nasal valve stenosis due, for example, to sinechia, is to be treated only surgically or with supportive devices, in cases of nasal valve collapse the surgical intervention can be avoided if the patient will be able to strengthen his nasal muscles responsible for the shape of nasal

*Received for publication: November 19, 2003; accepted: March 8, 2004

valve. This might be achieved by nasal neuromuscular training using visual electromyographic (EMG) feedback and/or a home exercise program of specific facial movements and possibly with electric stimulation of the involved muscles. Facial neuromuscular training with EMG biofeedback is well described (Duckett et al., 1994; Shiau et al., 1995; Segal et al., 1995; Brach et al., 1997). Biofeedback EMG instruments are essentially general purpose physiological monitoring devices that are designed to provide ongoing information about a physiological function, such as muscle tension level as measured by EMG. The process of monitoring and "feeding back" information to the patient is used to aid in training the patient to alter some characteristic of that activity.

At the same time, we did not find in literature any description of treatment using EMG feedback with a special emphasis to nasal muscles or to endonasal problems. As for electric stimulation as a possible treatment of nasal obstruction, selective nerve stimulation was primarily suggested for this purpose (Eisele et al., 1995; Series et al., 1999). Direct muscle electric stimulation was performed on the lingual musculature to treat obstructive sleep apnea and showed good results (Schwartz et al., 1996). Electric stimulation of facial muscles is used mainly for therapy of Bell's palsy (facial nerve paralysis). Electric stimulation of nasal muscles, in fact, is not developed.

The purpose of this paper is to describe the outcome of electric stimulation + exercise program + biofeedback training of nasal muscles in cases of nasal valve stenosis and/or collapse. The present study was performed to investigate the best way of using surface EMG in biofeedback training of muscles involved in nasal valve function and its possible combination with other ways of physical treatment.

## MATERIALS AND METHODS

### *Subjects*

The patients were selected across a 4-month period. Follow-up ranged from 8 to 12 months. The study was approved by the Medical Center Ethics Committee (outpatient department). Group 1 included 12 adults (n=12), all Caucasians, 6 women and 6 men, ranging in age from 22 to 56 years (mean = 29 years). Subjects had deviated nasal septum (7) and nasal valve collapse due to trauma (1), operation of rhinoplasty (3), and idiopathic weakness of nasal muscles (1). Group 2 included 12 adults (n=12), all Caucasians, 5 women and 7 men, ranging in age from 21 to 56 years (mean = 29,5 years). Subjects had deviated nasal septum (7) and nasal valve collapse due to trauma (1), operation of rhinoplasty (2), and idiopathic weakness of nasal muscles (2). Group 3 included 10 adults (n=10), all Caucasians, 5 women and 5 men, ranging in age from 24 to 55 years (mean 28 years). Subjects had deviated nasal septum (6) and nasal valve collapse due to trauma (2) and operation of rhinoplasty (2). Before the study, all subjects completed a questionnaire regarding their general health and their medical history. All selected subjects had no nasal valve stenosis due to unchangeable anatomical alterations. All subjects were examined by ENT physicians prior to their participation to the study.

Enrollment procedure:

Assessed for eligibility (n=73)

Excluded (n= 38)

a. Not meeting inclusion criteria (had anatomical stenosis with negative Cottle maneuver, usually as a result of severe septal deviation) (n=35)

b. Refused to participate (n=3)

Randomized (n=35)

| Allocated to | Group 1 (n=12) | Group 2 (n=12) | Group 3 (n=11) |
|---|---|---|---|
| Lost to follow-up | (n=0) | (n=0) | (n=0) |
| Discontinued intervention | (n=0) | (n=0) | (n=1) |
| Analyzed | (n=12) | (n=12) | (n=10) |

The Cottle maneuver is a simple test to detect any limitations in inhalation at the level of the ostium internum and the nasal valve is to pull the cheek lateral-wise during gentle inhalation through the nose. This sign is positive when inhalation noticeably improves with this maneuver. These 34 subjects were selected on the criterion of their nasal anatomical changes: patients with nasal valve collapse (or stenosis + collapse) and positive Cottle maneuver were included in the study; patients with severe nasal valve stenosis and negative Cottle maneuver were excluded.

### *Home exercise program of specific nasal movements*

The selected patients were learned to perform three movements of the nose (Figure 1):

1. To shorten the nose; instruction given to a patient: "Wrinkle your nose without knitting your brows. Do not make a complete wry face, just wrinkle your nose." This exercise helps to train 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 patient: "Move your nostrils down without knitting your brows or moving your lips and chin." This exercise helps to train mm. nasalis (both parts), the depressor septi and the compressor narium minor.
3. To narrow the nostrils; instruction given to a patient: "Try to dilate your nostrils without making a wry face". This exercise helps to train the alar portion of the nasalis muscle and the dilator naris anterior.

The patients were instructed to perform this program as many times a day as possible, 5 to 10 minutes each time, in front of a mirror. The movements are to be made rapidly, vigorously and indiscriminately to breathing. These exercises help to build up muscle strength and to teach a patient how to operate his nasal muscles. The program helps patients to become nasal muscles-conscious. Usually one month is enough to achieve these goals. During the second month of training, the patients are

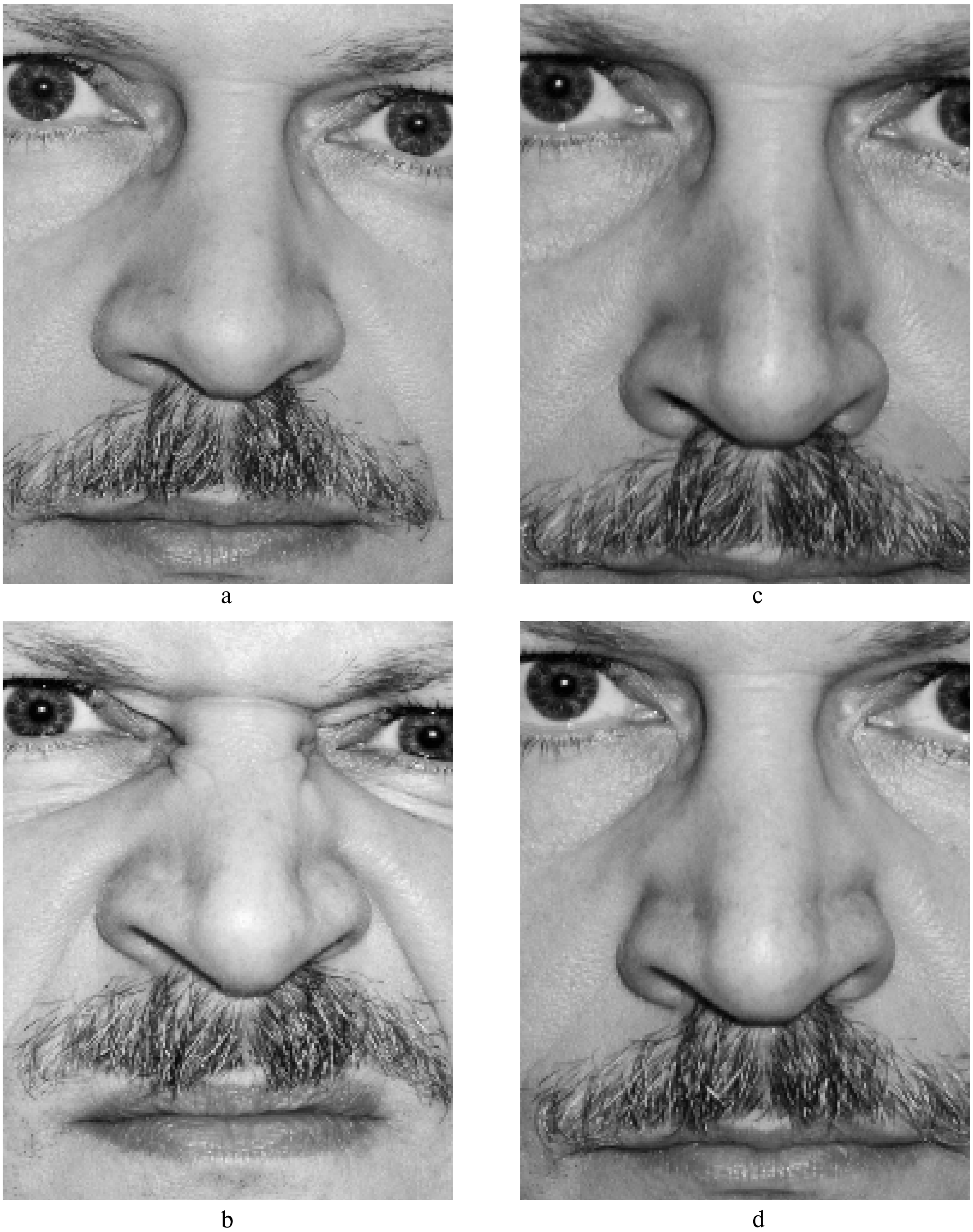


Figure 1. The movements of the nose during muscle exercises. a. normal position of the nose b. shortening the nose c. lengthening the nose d. dilation of the nostrils.

trained to widen the nostrils each time he/she inhales; they continue the exercises of the first month. Starting from the third month of training, the patients perform the initial three exercises only once in the morning, and their main effort is to breathe with open nostrils. In ideal, this additional movement of nasal muscles becomes automatic.

*Electric stimulation of nasal muscles*

Seven muscles were trained in the study: mm. levator labii superioris alaquae nasi, anomalous nasi, nasalis, dilator naris posterior, depressor septi, dilator naris anterior, compressor narium minor. All these muscles are superficial and they are involved in nasal valve movements.

For electric stimulation we used NeuroDyne 4 Channel MicroStim-1304D (NeuroDyne Medical Corp., Cambridge, MA, USA) micro-computer controlled muscle stimulator (Type II device by the FDA). It starts with symmetric, biphasic wave form which is then pulsed in trapezium shaped impulses, thereby good muscle contractions can be achieved easily with extremely soft and pleasant sensation being experienced by the patient. High voltage therapy is recommended for treatment (Frach et al., 1992; Eom et al., 2002) and we used 40 Hz conditioning stimulation to enhance the muscle force. The stimulation level (range 0.4 –40 mA, peak to peak) was determined on an individual basis. Timer was set for 15 minutes. Pulse rate was set for 200 pps with pulse width 600 microsecond.

For intranasal electric stimulation and for EMG biofeedback we used intranasal EMG sensor, which was previously described (Vaiman et al., 2003). This sensor (see Figure 2) 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. When it is used for electric stimulation, it can be attached to the muscle stimulator instead of surface electrodes or together with them.

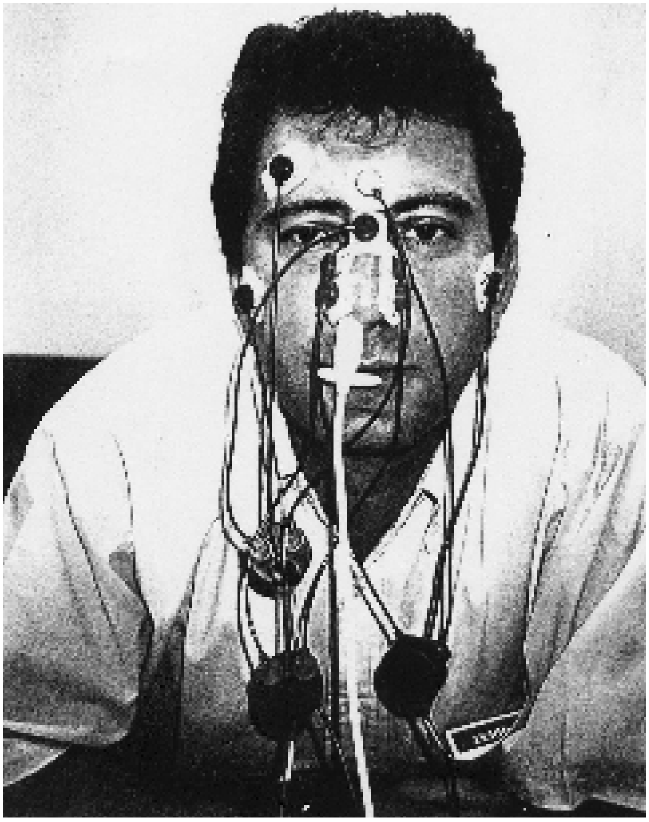

Figure 2. A subject with skin EMG sensors and intranasal EMG sensor, as used during biofeedback training. Each sensor occupies one channel of the EMG device.

*Electromyographic biofeedback technique*

This technique was applied to train the same seven muscles of the nose (Figure 2).

All surface EMG recordings were made using standard surface sensors AE-178. We used Neuromuscular Sys/3 four channel computer based EMG system with NeuroDyne Medical software (NeuroDyne Medical Corp., Cambridge, MA, USA), and AE-204 Active Electrodes. They have wide bandpass filter, bandwidth (RMS) 25-450 Hz and 60Hz notch filter. The system uses the Active Electrode, a compact sensor assembly that includes a miniaturized instrument preamplifier. Locating the amplifier at the electrode site allows artifacts to be cancelled and the signal boosted before being transferred down the electrode cable. 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.

For intranasal EMG biofeedback we used the intranasal EMG sensor mentioned above. 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 “Signagel” electrode gel, Parker Labs, Inc., New Jersey, or similar). Each intranasal EMG record also was full-wave rectified and low-passed filtered. This rectified and filtered record looks like a single line, similar to an EKG trace, easy to observe and understand.

EMG biofeedback consisted of three interrelated activities: 1) initial assessment of the amplitude (range, voltage) and graphic pattern of activity of above mentioned nasal muscles, 2) providing patients with feedback information about their physiological activity to aid them in learning to increase the amplitude and improve the graphic pattern, and 3) recording the process outcome of training using the physiological measures as objective data.

*Electromyographic biofeedback procedures*

After electrode placement, each participant performed three tasks:

1. normal nasal breathing; instruction given to a volunteer: “Breathe normally” – helps to establish the baseline;
2. forced nasal inspiration; instruction given to a volunteer: “Breathe as deep as you can but in normal pace” – helps to demonstrate changes in amplitude of muscle activity (curve tracing) during breathing to the patient;
3. breathing with widening of the nostrils; instruction given to a volunteer: “Try to move your nostrils to make them wider when you inhale, you should feel an increase of airflow and easy breathing” – helps to train the patient to breathe with open nasal valve.

After that the graphic patterns were analyzed with patient, correction given, explanations provided. For the main exercise, the external surface electrodes were removed except a pair above the nostrils, and subjects performed the training with this surface pair (1 channel) and with an intranasal electrode gently inserted (1 or 2 channels). Sometimes, when a patient was confused with two-channel recording, we used just one channel EMG record. When sensors were attached and set-up period was completed, a site location was indicated and baseline values (current level of activity of nasal muscles) were established by the computer program. We used three site locations: left nostril (intranasal), right nostril (intranasal), mm. nasalis and dilator naris anterior (surface). The goal setting was for increasing nasal muscle tension levels, i.e. to increase amplitude of the recorded curve. The amplitude represented strength of the muscles. The EMG protocol had goal and baseline display options, and lines representing the trial goal and the baseline reference appeared on the screen of computer when the training trials began. If the patient failed to increase the tension of his nasal muscles at least 50% of the time during a trial, the goal was adjusted to be easier at the start of the next trial. For success between 50 and 90%, the goal was left the same. For success above 90%, the goal was adjusted to be made more challenging for the patient. (New goal = (old goal + mean value for trial)/2). Each trial lasted for three minutes.

Single site Protocol 1: Trial 1 – left nostril; Trial 2 - surface location; Trial 3 – right nostril; Trial 4 – surface location.

Single site Protocol 2: single location is taken for several trials until the patient is tired (usually 4-8 trials).

Two-site biofeedback + Electric stimulation Protocol (Group 1): Start – surface electric stimulation for 5 min. Trial 1 – two nostrils; Trial 2 – left nostril + surface location; break – 5 min electric stimulation only. Trial 3 – right nostril + surface location; Trial 4 – two nostrils. End - surface electric stimulation for 5 min.

Two-site biofeedback Protocol (Group 2): Trial 1 – two nostrils; Trial 2 – left nostril + surface location; Trial 3 – right nostril + surface location; Trial 4 – two nostrils.

The curve tracing feature was used for EMG respiration training. It was used to train the patient to form a graph having a particular shape of a respiration with well controlled nasal muscles and nasal valve wide open. For neuromuscular education this was useful in giving the patient control over fine nasal movements, rather than just a coarse contraction. It was used to teach the patient to adjust nasal muscles contraction with normal breathing pace.

Patients performed biofeedback training (or biofeedback + electric stimulation) three times a week during first 6 weeks. In addition to that, the subjects of Group 3 received separate electric stimulation 15 min sessions between biofeedback training sessions 2 times a week. Afterwards, for Groups 3 and 2, subjects had one training a week for the next six weeks. In Group 1, each patient received 10-week treatment with electric stimulation only, which included 30 séances 15 minutes each every other day (three times a week). First 15 séances patients received general electric stimulation of the nasal muscle area (Figure 3), and next 15 séances they received local stimulation of the muscles less responsive to the procedure (Figure 4). During further follow-up visits the EMG records of nasal muscle activity were obtained every month.

## RESULTS

Subjective self-assessment data for nasal airflow were collected. Objective data were provided by

- pretreatment and post-treatment clinical observation
- nasal endoscopy during the treatment and follow-ups (Figure 5)
- anterior rhinomanometric evaluation (Rhinomanometer NR6, GM Instruments, Scotland, UK)
- acoustic rhinometry evaluation (GMI A1 Acoustic Rhinometer, GM Instruments, Scotland, UK) (Figure 6)
- surface and intranasal EMG records before during the treatment and follow-ups (Figures 7 and 8)

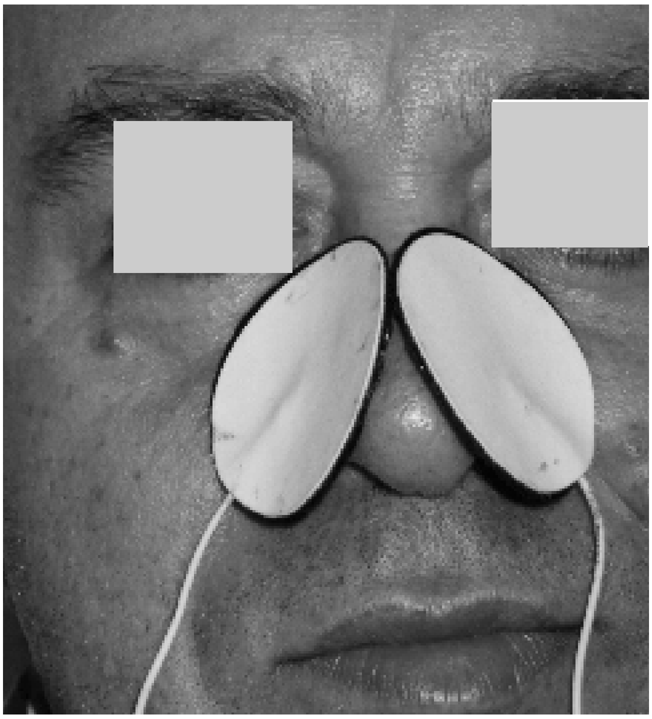

Figure 3. General electric stimulation of the nasal muscle area.

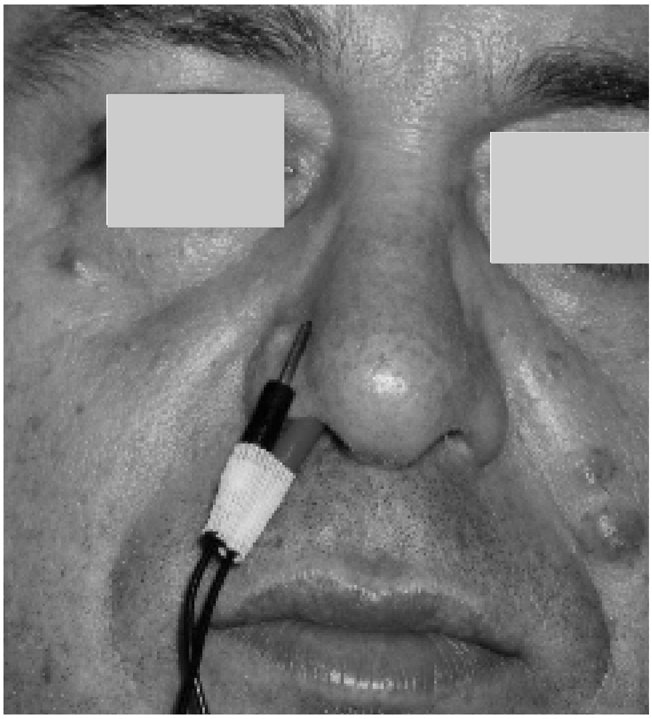

Figure 4. Local electric stimulation of the muscle that is less responsive to the procedure. The picture shows stimulation of the apical nasal muscle.

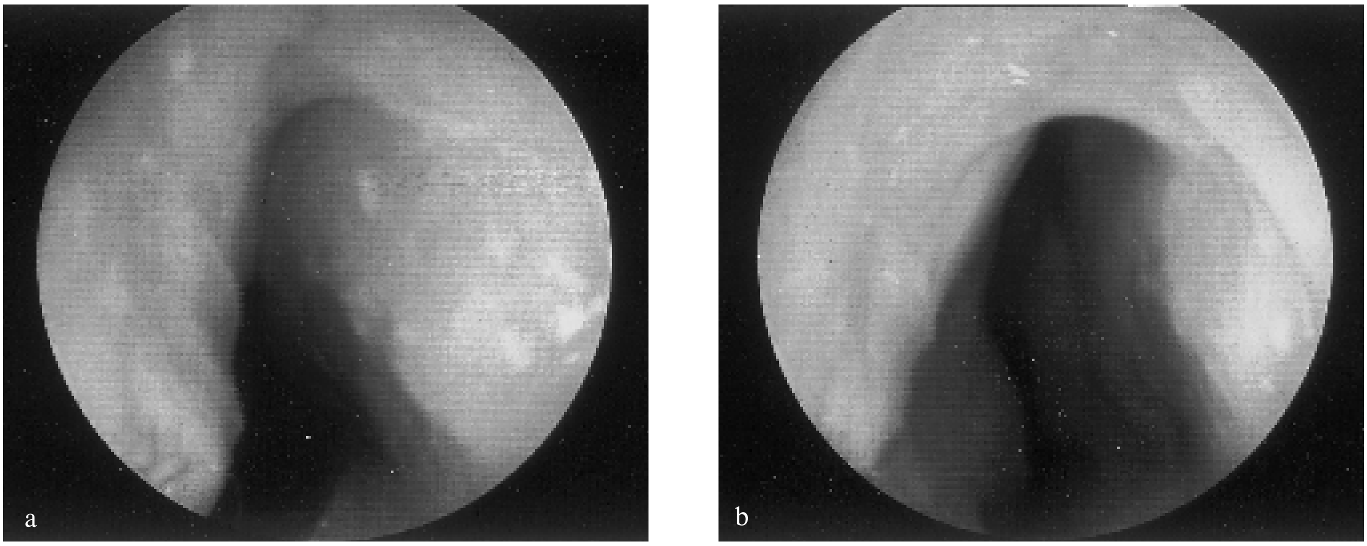


Figure 5. Endonasal pictures of nasal valve before (a) and after (b) treatment. Follow-up after 9 months.

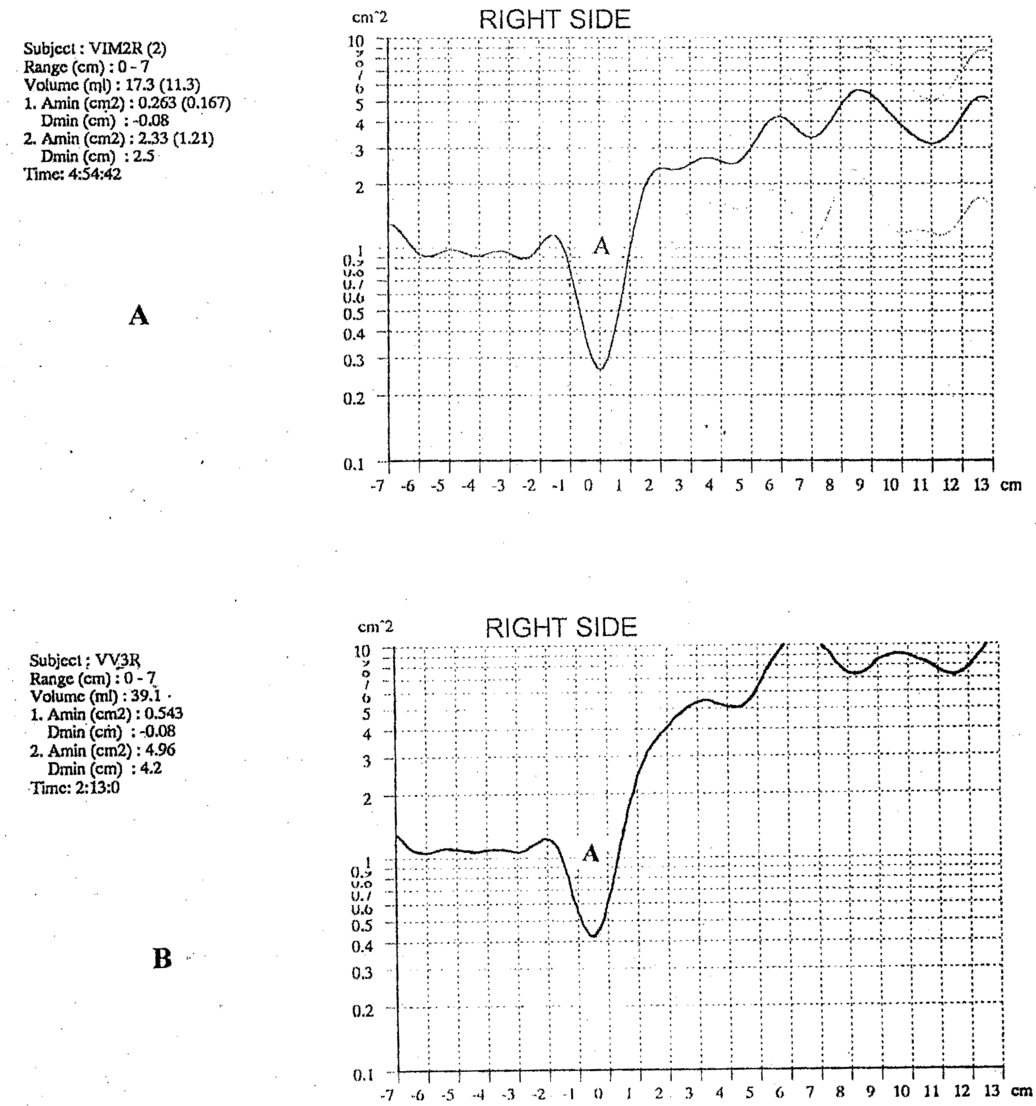


Figure 6. A. Acoustic rhinometry of a patient from Group 1 before the treatment. (A) – nasal valve curve; nasal valve cross section – 0.263 $cm^2$. Volume measurement: 17.3 ml. B. The same patient after 4 months of treatment. (A) nasal valve curve; nasal valve cross section – 0.543 $cm^2$. Volume measurement – 39.1 ml.

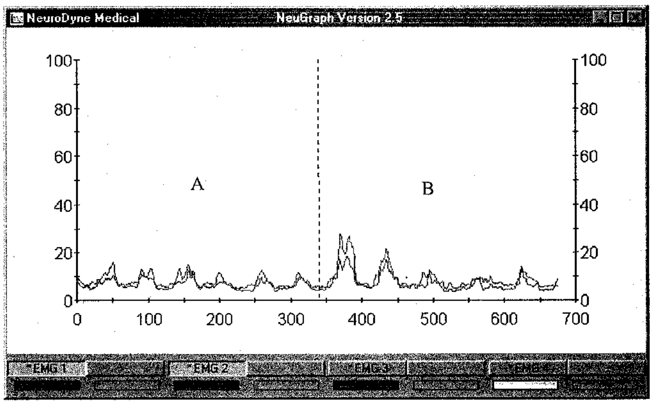


Figure 7. An EMG 2-channel (surface + intranasal) record of breathing of a patient (F, Group 2) with symptoms of obstructed nasal breathing and clinically evident nasal valve collapse. A – normal breathing; B – deep breathing. The patient operates her nasal muscles poorly. In deep breathing attempt her muscles became exhausted after two inhales, deep breathing is achieved mainly with the help of chest muscles. Intranasal sensor record is slightly above the record from the surface skin electrode.

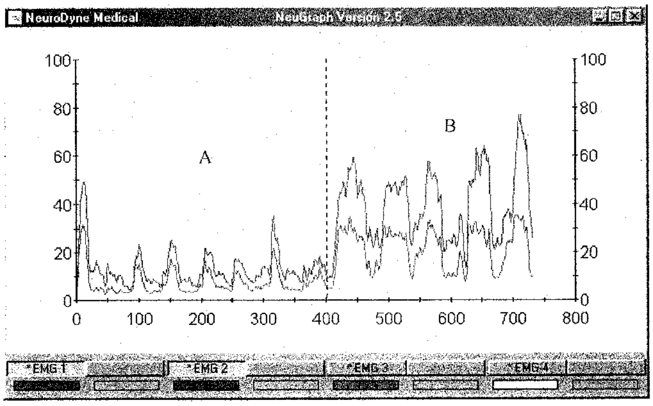


Figure 8. The same patient from Group 2 after complete course of EMG biofeedback training and home exercise program, follow-up visit after 10 months. A – normal "nasal-valve-open" breathing; B - deep breathing. Intranasal sensor record line is above the record from the surface skin electrode.

Multivariate analyses of variance for repeated measures were used to analyze the results before and after training (mean interval, 41.3 weeks). In Group 3, after treatment 8 patients (80%) had increased airflow, i.e. bilateral inspiratory nasal flow increased ($p < 0.001$). All patients reported subjective improvement. Nasal inspiratory resistance significantly decreased ($p < 0.0001$) in 7 patients (70%). Minimal cross-sectional area in the nasal cavities (actually, in the anterior cavum) increased in 7 patients (70%). EMG recorded amplitude of muscle tension of the nasal muscles (in $\mu$V) significantly increased in all 10 patients (100%) ($p < 0.001$), i.e. strength of the nasal muscles was increased.

In Group 2, after treatment 9 patients (75%) had increased airflow, i.e. bilateral inspiratory nasal flow increased ($p < 0.001$). All patients also reported subjective improvement. Nasal inspiratory resistance significantly decreased ($p < 0.0001$) in 8 patients (66.66%). Minimal cross-sectional area in the nasal cavities increased in 7 patients (66.66%). EMG recorded amplitude of muscle tension of the nasal muscles significantly increased in 11 patients (91.66%) ($p < 0.001$).

In Group 1, where the only treatment was electric stimulation, after treatment 7 patients (58.33%) had increased airflow, i.e. bilateral inspiratory nasal flow increased ($p < 0.01$). Ten patients reported subjective improvement (83.33%). Nasal inspiratory resistance significantly decreased ($p < 0.005$) in 6 patients (50%). Minimal cross-sectional area in the nasal cavities (actually, in the anterior cavum) increased in 6 patients (50%). EMG recorded amplitude of muscle tension of the nasal muscles (in $\mu$V) significantly increased in 9 patients (75%) ($p < 0.005$), i.e. strength of the nasal muscles was increased.

We found no significant difference between the results in Groups 3 and 2, while the results in Group 1 were obviously less impressive.

## DISCUSSION

Nasal valve collapse may be iatrogenic or can occur as a consequence of ageing or trauma. In case of facial muscle problems, electromyographic feedback is used mostly in the treatment of facial nerve paralysis (Gallegos et al., 1992; Diels, 1994; Segal et al., 1995). We first used EMG biofeedback-assisted specific protocols for nasal muscle training and a home exercise program of specific nasal movements to treat endonasal disorders. We then tried to reinforce the same treatment with various types of electric stimulation of nasal muscles but observed very limited additional effect. We found this technique very useful in treatment of the patients with symptoms of obstructed nasal breathing who wish to avoid surgical operation or supportive devices.

Recent report on measurement of force and the electromyogram of human nasal dilator muscles confirmed the fact that the upper airway respiratory muscles play important role in the regulation of airway resistance (DelloRusso et al., 2002). While the dilator naris anterior and the alar part of the m. nasalis are very active in nasal valve regulation, the direct influence of the depressor septi and the levator labii superioris alaquae nasi on the nasal valve is not yet clear. In any case, we advise to train all muscles of the nose. We report positive short- and medium-term functional results of our approach and conclude that described procedure offers an improvement in nasal airway performance in patients with nasal valve collapse without surgical intervention.

The intranasal sensor/electrode was used to introduce different variations of the biofeedback training and electric stimulation, aiming to involve as many nasal muscles as possible and, at the same time, to avoid involvement of the groups of facial muscles not related to nasal area. Our patients reported that using of intranasal sensor helped them to perform training because they felt a bearing inside the nose to support alae of nostrils. 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 EMG biofeedback treatment. When the two intranasal sensors are inserted, they can serve for quick objectivization of left-right nostril differences in cases of stroke, Bell's palsy, septal deformity and similar. In biofeedback training this objectivization should be used during initial explanation of the problem to a patient.

## CONCLUSION

We conclude that significant relieve of nasal valve stenosis and collapse can be achieved with biofeedback training of nasal muscles and a home exercise program as described. It helps a significant cohort of patients with symptoms of obstructed nasal breathing to avoid surgical intervention. The method is simple, noninvasive and has good results. The electric stimulation of nasal muscles can be used as an additional treatment but does not contribute significantly in improvement of the results.

## REFERENCES

1. Brach JS, Van Swearingen JM, Lenert J, Johnson PC (1997) Facial neuromuscular retraining for oral synkinesis. Plast Reconst Surg [issue] 1922-1931.
2. DelloRusso C, Khurana N, Rankin L (2000) Mechanisms of force failure during repetitive maximal efforts in a human upper airway muscle. Muscle nerve 202 26: 94-100.
3. Diels HJ (1994) Treatment of facial paralysis using electromyographic feedback – a case study. Eur Arch Otolaryngol Suppl [issue] S129-132.
4. Duckett S, Kramer T (1994) Managing myoclonus secondary to anoxic encephalopathy through EMG biofeedback. Brain Inj 8: 185-188.
5. Eisele DW, Schwartz AR, Hari A (1995) The effect of selective nerve stimulation on upper airway airflow mechanics. Arch Otolaryngol Head Neck Surg 121: 1361-1364.
6. Eom GM, Watanabe T, Hoshimiya N, Khang G (2002) Gradual potentiation of isometric muscle force during constant electrical stimulation. Med Biol Eng Comput 40: 137-143.
7. Frach JP, Osterbauer PJ, Fuhr AW (1992) Treatment of Bell's palsy by mechanical force, manually assisted chiropractic adjusting and high voltage electrotherapy. J Manipulative Physiol Ther 15 9: 596-598.
8. Gallegos X, Medina R, Espinoza E, Bustamante A (1992) Electromyographic feedback in the treatment of bilateral facial paralysis: a case study. J Behav Med 15: 533-539.
9. Haight JS, Cole P (1983) The site and function of the nasal valve. Laryngoscope 93: 49-55.
10. Rhee JS, Book DT, Burzynski M, Smith TL (2003) Quality of life assessment in nasal airway obstruction. Laryngoscope 113: 1118-1122.
11. Schwartz AR, Eisele DW, Hari A (1996) Electrical stimulation of the lingual musculature in obstructive sleep apnea. J Appl Phisiol 81: 643-652.
12. Segal B, Hunter T, Danys I (1995) Minimizing synkinesis during rehabilitation of the paralyzed face: preliminary assessment of a new small-movement therapy. J Otolaryngol 24: 149-153.
13. Segal B, Zompa I, Danys I (1995) Symmetry and synkinesis during rehabilitation of unilateral facial paralysis. J Otolaryngol 24: 143-148.
14. Series F, Demoule A, Marc I (1999) Inspiratory flow dynamics during phrenic nerve stimulation in awake normals during nasal breathing. Am J Respir Crit Care Med 160: 614-620.
15. Shiau J, Segal B, Danys I (1995) Long-term effects of neuromuscular rehabilitation of chronic facial paralysis. J Otolaryngol 24: 217-220.
16. Vaiman M, Eviatar E, Segal S (2003) Intranasal electromyography in evaluation of the nasal valve. Rhinology 41: 134-141.

Michael Vaiman
33 Shapira Str.
Bat Yam 59561
Israel

Tel: +9723-553-6139
Fax: +9723-553-6137
E-mail: vaimed@yahoo.com