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ORIGINAL ARTICLE

The treatment and results of voice therapy amongst professional classical singers with vocal fold nodules[1]

SEMYON I. CHERNOBELSKY

Department of Phoniatrics, Voice Research Laboratory of the State Opera and Ballet Theatre, and the Music College, Krasnoyarsk, Russia

Abstract
In order to test the hypotheses that nonsurgical treatment and elimination of inappropriate use of the voice is sufficient for disappearance of vocal fold nodules (VN), 28 classical singers with these lesions were examined for a period of up to 24 years after establishing this diagnosis. Twenty vocally healthy female singers constituted the control group. Laryngoscopy, microlaryngoscopy, laryngostroboscopy and acoustic voice analyses were used to carry out this research. It was found that VN, having once occurred, tended to reoccur despite nonsurgical treatment and the elimination of incorrect singing. It was concluded that physiologically correct singing leads only to a temporary disappearance of soft nodules and does not promote the resolution of hard nodules.

Key words: *Acoustic voice analyses, laryngostroboscopy, singing voice, vocal abuse*

Introduction

Vocal fold nodules (VN) are benign focal lesions of the vocal folds, thought to arise as a result of vocal abuse, and which significantly deteriorate vocal quality (1–6). Typically, nodule formation occurs symmetrically on the free edge of the vocal folds at the junction of the middle and anterior third of the folds. Histologically, VN present anomalies of the epithelium and the subepithelial space of Reinke, and, depending on the maturation process, can be edematous (soft) or fibrous (hard). Many theories have addressed the mechanisms by which VN develop. In one prevailing theory, the vocal folds are mechanically traumatized in the process of phonation (7–10).

Voice therapy has a positive effect on voice quality, vocal status, and vocal facility in the majority of patients with VN. However, videostroboscopic evaluations indicate that in no cases are VN completely resolved by therapy (2). Performing artists have generally approached phonomicrosurgery with great trepidation, and therefore data on singers who have undergone such surgery is scarce. Nevertheless, some authors (1,6,11–13) recommend this treatment if behavioral management has had no effect.

Some singing teachers and phoniatricians consider that nonsurgical treatment and elimination of inappropriate use of the voice is sufficient for the complete and irreversible disappearance of VN (14). As a result, Russian Music Colleges have tended to accept all candidates with these lesions who can nevertheless demonstrate an excellent voice. The present study was carried out in order to test the supposition that VN could be irreversibly resolved after nonsurgical treatment and elimination of incorrect singing.

Material and method

Twenty-eight professional classical singers aged between 18 and 43 years (1 male and 27 female) with VN constituted the main group. This retrospective investigation was based on opportunity samples.

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Correspondence: Professor Semyon I. Chernobelsky, MD, Dubrovinsky St. 56-20, Krasnoyarsk 660049, Russia. Fax: +7 3912 279390. E-mail: semyon@ktk.ru

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Each subject was, when first examined, a student of the Krasnoyarsk Music College, and subsequently became a professional singer of one of the following institutions in the same town: the State Opera and Ballet Theatre, the State Operetta Theatre, the Philharmonic Society or other professional choruses. It is a routine part of a singer's life in Russia (both for professionals and students) to be periodically examined by a phoniatrician. When vocal problems occur, singers are often examined weekly or even daily. It is as a result of the author's position as phoniatrician at the above institutions that the data for this study was gathered.

The male singer had hard VN, which was diagnosed 5 years after leaving college. Amongst the females, hard VN was diagnosed in 5 of the subjects and soft VN was diagnosed in the remaining 22. In each of the female subjects with hard VN the condition was revealed before entering Krasnoyarsk Music College. Each singer with these lesions had had vocal experience and had indicated vocal complaints for at least 1 year before entering college. All the female singers with hard VN had excellent voices and were therefore allowed to enter music college. In all of the singers with soft VN the diagnosis was made during their period of study at college. None of these subjects had had vocal experience or voice complaints before study. All the singers from the main group had only one teacher during their period of study at college. However, after leaving college most of the singers changed teachers at least three times.

All the singers were periodically reexamined after establishing their diagnosis. Ten of the female subjects were examined over a period of 24 years (from 1980 to 2004), 12 of the females were examined over a period of 20 years (from 1984 to 2004), the male was examined over a period of 15 years (from 1989 to 2004), and the other 5 females were examined over a period of 10 years (from 1994 to 2004). In none of subjects was VN resolved irreversibly. None of singers suffered from acid reflux or the inhalation of airborne irritants, both of which can lead to inflammation of the vocal folds and can be aggravating factors in the development of VN. Twenty vocally healthy female singers of matched age and experience constituted control group. None of the females from either group used oral or intrauterine contraceptives. All the females had a normal menstrual cycle. The subjects were all nonsmokers.

Financial limitation did not allow us to use videostroboscopy of the larynx, thus data were obtained using mirror laryngoscopy and microlaryngoscopy (microscope K. Zeiss OBMI VARIO). Laryngostroboscopy, which was performed using chest register and soft phonation, was carried out using a laryngostroboscope ELS-03 (Russia). From 2002 to 2004 videolaryngoscopy was conducted on all patients. For this we used rigid endoscope PH402718C 70°, digital endoscopic video camera EVC-001 S-VHS and color video monitor W 3502 S-VHS 37 cm (company 'Eleps', Russia).

From 2001 to 2004 acoustic analyses of the voice were carried out in females before and after treatment using the software package 'Praat' (15). The following data were gathered: speaking fundamental frequency (SF0), jitter (F0 perturbations in the period of vibrations), shimmer (F0 perturbation in the amplitude of vibrations) and signal-to-noise ratio (S/N) (the proportion of noise in the voice). Jitter (local) was calculated as the ratio of the mean absolute difference in consecutive periods to the mean period (Multidimensional Voice Program (MDVP) calls this parameter *Jitt*). Shimmer (local) was calculated as the ratio of the mean absolute difference in the amplitudes of consecutive periods to the mean amplitude (MDVP calls this parameter *Shim*). An IBM-compatible Celeron 366 MHz computer was used for both data acquisition and analysis. To estimate SF0, the subjects were asked to read the same passage of Russian text with an intensity level of around 60 dB for a period of about 30 seconds. To estimate jitter, shimmer and S/N ratio, the singers were asked to produce the vowel /a:/ in chest register at a comfortable frequency and with an intensity level of around 60 dB for 3–4 seconds. Highpass and lowpass filters (10 Hz and 5000 Hz, respectively) were applied to the input signal. All sample readings were taken before the subjects had sung that day, and at approximately the same time (between 14.00 and 15.00) in a well damped room using a measuring microphone Gembird EMIC-111.

The mouth-to-microphone distance was 30 cm as recommended by Baken and Orlikoff (16). Amongst the females, investigations were conducted outside of menses. The acoustic results were statistically analyzed using Student's *t*-test and constitute Table I.

Results

Hoarseness of the speaking and singing voice, breathiness, pitch breaks and difficulty with using the voice at a *piano* dynamic were the most common symptoms of which patients complained. The inability to use the voice in falsetto register appeared in the male singer. Most subjects frequently attempted to clear their throats.

Laryngoscopy and microlaryngoscopy revealed pimple-like symmetrical lesions on the free edge of the vocal folds. Soft formations had edematous

Table I. The acoustic values.

Group	Subjects	SF0 (Hz)	Jitter (%)	Shimmer (dB)	S/N (dB)
Control	20	R: 190.1–259.2 M: 234.5 SD: 21.7	R: 0.22–0.36 M: 0.26 SD: 0.04	R: 0.31–0.85 M: 0.62 SD: 0.17	R: 13.1–20.0 M: 17.7 SD: 2.6
Main	pretherapy: 27	R: 207.1–292.2 M: 231.0 SD: 31.2	R: 0.45–1.32 M: 0.71 SD: 0.30	R: 0.50–1.78 M: 1.20 SD: 0.46	R: 9.2–16.3 M: 12.2 SD: 2.5
	posttherapy: 27	R: 185.0–260.0 M: 230.2 SD: 27.6	R: 0.22–0.40 M: 0.30 SD: 0.04	R: 0.35–0.90 M: 0.70 SD: 0.20	R: 14.0–17.0 M: 16.8 SD: 2.9

SF0 = speaking fundamental frequency; S/N = signal-to-noise ratio; R = range; M = mean; SD = standard deviation.

consistency and were pink in color. Fibrous ones had firm consistency and were whitish in color. Glottic closure was incomplete in both soft and hard VN and had an hourglass form. Stroboscopy did not reveal violation of the periodicity of vocal fold vibration in soft VN and revealed aperiodic vibrations in hard VN. Symmetry of vibration was not affected in either type of lesion. The amplitude of the vibration was normal in both soft and hard VN. In subjects with soft VN the mucosal waves were slightly decreased at the site of the lesions; vibratory closure in these cases was sufficient. In subjects with hard VN the mucosal waves were markedly decreased at the site of the lesions, and vibratory closure was insufficient.

Differences between SF0 values of subjects in the main group and those in the control group were very small and nonsignificant ($p > 0.05$). Jitter and shimmer values of patients with VN were considerably higher than in healthy singers (Figure 1a, 1b), and the S/N ratios in the main group were considerably lower than in healthy subjects (Figure 1c). The differences between these magnitudes were significant ($p < 0.001$). These observations confirmed the pathology.

In all cases treatment of VN began with 2 weeks of vocal rest. In eight subjects with relatively acute soft formations laryngoscopy confirmed the disappearance of lesions after rest alone; these singers also experienced a significant improvement in vocal quality. Laryngostroboscopy revealed symmetrical, periodic vocal fold vibrations with sufficient vibratory closure. The vibratory amplitudes and the mucosal waves were normal in size. In the remaining 14 singers with soft VN, the lesions were not resolved after vocal rest. Ultrasound therapy with corticosteroid ointment in the region of the larynx was therefore undertaken. Apparatus 'LOR-1A' (made in Russia) was used for this purpose. The treatment was performed using continuous output with a working frequency of 880 kHz, intensity of

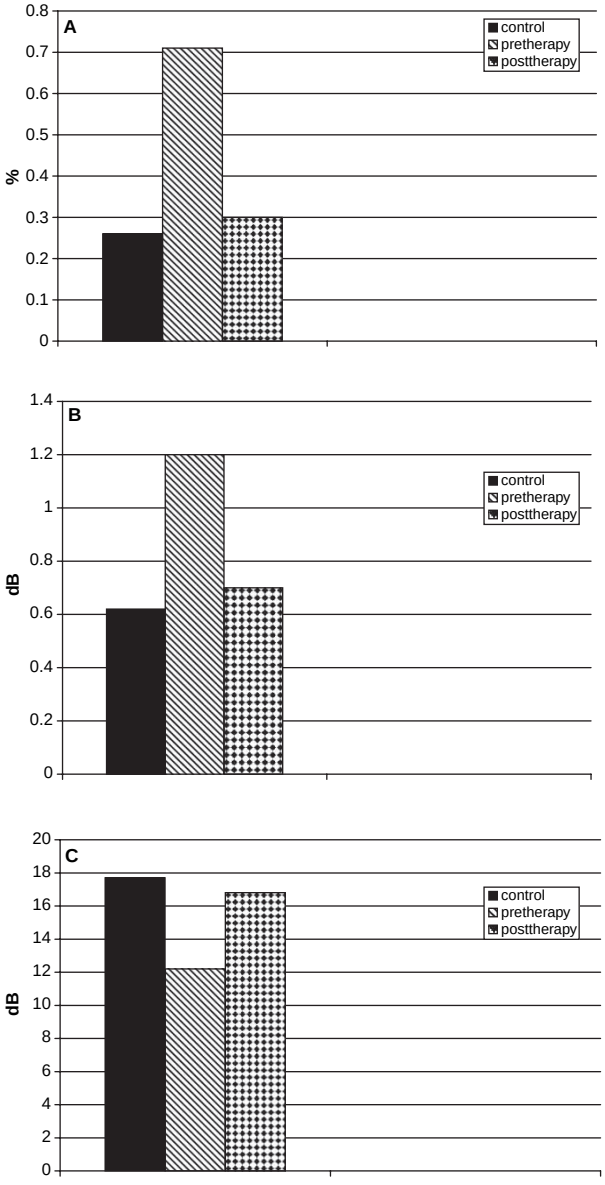

Figure 1. Graphical display of acoustic analyses of the voice. A: Jitter; B: Shimmer; C: Signal-to-noise ratio (S/N).

0.4 watt/cm^2, and an ultrasound emitter contact area of 2 cm^2. Hydrocortisone ointment 0.5% was used as a contact medium for this purpose. An emitter was positioned alternately on each side of the thyroid alae, and treatment lasted for 12 minutes per day (6 minutes on each side) over a period of 10–15 days. The emitter was kept stationary during treatment.

After ultrasound therapy resolution of soft nodules in all 14 subjects was observed by means of laryngoscopy, and there was a perceived improvement in the quality of the voice. Laryngostroboscopy revealed symmetrical, periodic vocal fold vibrations with sufficient vibratory closure. The vibratory amplitudes and the mucosal waves were normal in size.

In the male singer and the five female singers with hard VN, laryngoscopy after 2 weeks of vocal rest revealed no change in the size of the lesions, and there was no perceived improvement in vocal quality. After ultrasound treatment hoarseness slightly decreased. The examination of the larynx revealed decreased size of fibrous formations, but in no subject did the lesions completely disappear. Stroboscopy indicated symmetrical, periodic vocal folds movements with insufficient vibratory closure. The mucosal waves at the site of the lesions were significantly decreased and the sizes of the vibratory amplitudes were within normal limits.

Comparison of SF0 values in all voice subjects pre- and posttherapy showed differences to be very small and nonsignificant ($p > 0.05$). By contrast, decrease of jitter and shimmer values (Figure 1a, 1b) and increase of S/N ratio values (Figure 1c) posttherapy were considerable and significant ($p < 0.001$) in all subjects, and this was reflected in reduced vocal hoarseness.

After treatment, subjects began singing lessons for the correction of their vocal technique. Lessons were short, and repertoire was simple. Unsupervised singing was prohibited. This stage lasted for a period of 2–3 months.

During this time nodules did not reoccur in any of the 22 subjects with soft VN; however, when the vocal load was subsequently increased, the nodules invariably reappeared. When this happened, singers were instructed to rest their voice for 2 weeks, or to resume ultrasound treatment if VN did not disappear after vocal rest. As a result, students became frequent visitors to the phoniatrician throughout their years of study. After leaving college, singers continued to experience the same problems.

In the five females with hard nodules the lesions did not disappear after elimination of inappropriate use of the voice. Three of them were forced to leave college during their first year of study: they attempted unsuccessfully to study at other music colleges and also tried changing teachers, but finally lost hope of becoming professional solo classical singers; they did, however, manage to obtain places in the chorus. The remaining two singers showed great ability to compensate for incomplete glottic closure and completed their studies. During professional work, in order to improve their voice they were required to do long vocal 'warm-up' exercises, after which their nodules became flatter. But after strong singing, laryngoscopy on subsequent days revealed that the lesions had considerably increased in size as a consequence of edema of the vocal fold margins; both their singing and speaking voices were affected. Stroboscopy revealed aperiodic and asymmetric vibration of vocal folds with increased amplitude, increased mucosal waves and insufficient vibratory closure. Acoustic data confirmed the pathology. The mean SF0 value was 218.2 Hz; mean values for magnitudes of jitter and shimmer were 1.12% and 1.90 dB, respectively; the mean S/N ratio was 10.9 dB. These singers needed at least 7 days of vocal rest after strong singing, thus they could perform demanding roles only three or four times a month. The male subject, who had hard nodules, experienced the same problems.

Discussion

According to this investigation, VN was revealed to be much more common in females than in males. Chagnon and Stone (17) suggest that the greater susceptibility of the female larynx can be explained by its being subject to hormone-related effects, which appear around menses. At these times, all female singers were required to refrain from singing altogether; however, the majority did not keep to this rule, preferring to sing every other day. According to our previous investigation, vocally abusive singers who used their voice around menses constituted a high-risk group for the development of VN as a consequence of the combined vocal abuse- and menses-related changes to the larynx (18). In the male singer (a lyric baritone) hard nodules appeared after leaving college, and were a result of long-term unrestrained performing of roles excessively dramatic for his voice type.

Vocal trauma is the main reason for the appearance of VN. Hirano et al. (19) suggest that nodules result from direct hammering or slapping effects during falsetto patterns of vocal fold vibration when vibratory movements are maximal at the edges of the folds. Some authors (20,21) have emphasized the role of vocal trauma in the formation of microhematomas and subepithelial edema, which could lead to the appearance of VN. Despite the fact that there are many vocally abusive singers, nodules

tend to occur and reoccur only in certain individuals. The reason is probably that in these cases there is an inherent structural weakness of the vocal folds. According to Gray (8), electron microscope findings in nodules indicate that the basement membrane zone of the vocal fold had been subjected to repeated injury that resulted in disorganization of the normal structures. Because of these changes it is likely that the basement membrane zone is functionally less able to provide secure attachment of the superficial layer of lamina propria to the epidermis. This might play a role in the development of VN.

Stroboscopy is very helpful in the diagnosis of VN and for the evaluation of fluctuations in pre- and posttherapeutic results (22,23). In our study this method was more effective in obtaining information about hard VN than soft. Hoarseness appeared as a result of aperiodicity of vocal fold vibrations, which was found in patients with hard VN before treatment. Insufficient vibratory closure of the glottis during the vibrations caused the vocal quality to be breathy. The status of the mucosal waves was the most important factor for the differential diagnosis between soft and hard formations: edematous lesions impaired the mucosal waves less than did fibrous ones.

In two of the patients with hard VN, in addition to aperiodicity and insufficient vibratory closure, there were asymmetric vibrations with increased amplitude and increased mucosal waves after strong singing. The asymmetric vibrations occurred as a result of inconsistent mechanical properties of the vocal folds; their increased amplitude and increased mucosal waves resulted from reduced tension in the vocal muscles. Posttherapy, the vocal folds of patients with hard VN produced periodic vibrations, which were perceptually associated with decreased hoarseness. However, vibratory closure in these cases still remained insufficient and this resulted in the voice sounding breathy. The mucosal waves were still significantly decreased at the site of the VN.

Acoustic voice analysis indicates the status of the phonatory system. Anything that increases the effective mass of the vocal fold, including nodules, will tend to lower the SF0 (16). However, in our research we did not find differences in SF0 pre- and posttherapy. Sataloff (24) explained the same phenomenon by the greater ability of professional singers (unlike nonsingers) to compensate for this lowering of the SF0. Significantly lowered SF0 was found in only two of the singers with hard VN, and only after strong singing. This reflected essential growth in mass of the VN.

Increased fundamental frequency perturbations (jitter and shimmer) are associated with the perception of vocal hoarseness (16). Increased values of these magnitudes in subjects with VN, unlike healthy subjects, indicated vocal pathology. Decreased values of magnitudes of jitter and shimmer, which were found in patients post therapy, reflected a diminishing in size of the nodules. Yumoto et al. (25) consider that the S/N ratio is the objective index of the degree of vocal hoarseness. Because patients with VN generally produce higher levels of vocal noise, their S/N ratios are lower than those of healthy singers. There is a considerable increase of this ratio post therapy, indicating a reduction in the vocal noise.

Nonsurgical treatment of patients with VN takes various forms. Total vocal rest is commonly prescribed to all patients. Many clinicians have observed resolution of VN with vocal rest alone, from 2–3 days to 2 weeks (if these lesions were relatively acute) (26,27). According to McCrory (28), results of speech and language therapy in patients with VN demonstrate the elimination of lesions in over 70% of cases. The same findings are reported by Yamaguchi et al. (29). Some studies provide evidence of therapeutic benefit from hydration treatment (30,31). The most common medical treatment for VN is oral, anti-inflammatory corticosteroids, which decrease edema as well as inflammation, and is frequently used by professional singers (32,33). In 1948 Pohlman (34) established that medicines could be inserted into the human body by means of ultrasound. Vasilenko (35) supposed that treatment of VN using ultrasound with hydrocortisone ointment in the region of larynx might be more appropriate than oral corticosteroids. He reported elimination and/or reduction of VN in over 80% of patients with VN.

Having started vocal study, singers usually cannot bring themselves to give up, even when there is no improvement in their singing. When given the opportunity to perform taxing roles at an early stage in their careers, they seldom turn it down, even when the voice is too immature, or simply inadequate in strength. This could explain why some of those who have the best voices also suffer from VN (36).

The diagnosis of 'VN' has a powerful psychological effect on singers. They often conceal their diagnosis and seek consultations with other phoniatricians in the hope of obtaining a different diagnosis, not wishing to believe that they must reduce the scope of, or even abandon, their singing careers (37).

In Russian opera houses, prospective soloists are examined by a phoniatrician before a contract is

signed. VN can be the reason for an opera house refusing to sign a contract even when the singer has an excellent voice. Before entering music college, all candidates are examined by a phoniatrician. If VN is given as the reason that they cannot be accepted, singers frequently seek treatment using nonsurgical methods and, after vocal improvement, try to enter music college in other towns, concealing the fact of having been diagnosed with VN in the past. During their study at college, they tend to attribute any medical problems with their voice or failure to progress in their studies to inappropriate vocal technique and poor teaching. For this reason, such singers frequently change teachers in order to improve their vocal technique; meanwhile, teachers' methods of vocal training vary considerably. This allows us to suppose that the concept of 'physiologically correct singing' is actually very subjective.

We did not share the optimism of most of the people involved in the care of singers with VN concerning the responsiveness of appropriate nonsurgical treatment and voice therapy; nor do we share the view of certain authors that microsurgery is an appropriate treatment in cases where behavioral therapy fails (9,12,13). Based on our investigation VN, having occurred once, tends to reoccur despite vocal rest, medical treatment and elimination of inappropriate use of the voice. In the light of these findings, it should therefore be recommended that singers with VN should not enter music college unless they can display exceptional musical talent; however, if having done so, and as a result of VN their singing voice does not improve during their period of study, they should be discouraged from pursuing careers as classical singers.

Singers hold back from surgical treatment because of possible complications; they prefer to change their vocal technique, but there is invariably is a deterioration of their vocal quality. We did not confirm the view that elimination of inappropriate use of the voice is sufficient for complete resolution of VN. Teachers simply used long-term facilitated vocal loading, which led to the temporary resolution of soft nodules, and which was completely ineffective with hard nodules.

The strength of the present study results from the privileged position that the author had as resident phoniatrician at Krasnoyarsk's music college and opera theatre. It was therefore possible to examine all the subjects frequently, and over a long period of time (up to 24 years). The weakness of the study is that the sample was relatively small, with male data based on one person only. Financial limitations did not allow us to use videostroboscopy of the larynx in this research. We would like to point out that monitoring of the subjects in this study is continuing and ongoing. Keeping in mind, therefore, the limitations which such a study has, we would hope to extend it in future.

Conclusions

Vocal fold nodules, having occurred once, tend to reoccur despite nonsurgical treatment and voice therapy. Physiologically correct singing leads only to a temporary disappearance of soft nodules and does not promote the resolution of hard nodules.

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