Evaluation of Vocal Efficiency for the Polyps and Nodules

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= Abstract =

The vocal efficiency(VE) can be calculated as the ratio of acoustic power to aerodynamic power. It relates to the vocal intensity, air flow rate and subglottic pressure. In this study, we treated 20 cases of vocal polyps and 10 cases of vocal nodules by way of laryngo-microsurgery or laser laryngo-microsurgery. The VE was measured preoperatively and postoperatively in all cases. The results showed that there was a significant improvement of VE postoperatively than that of preoperative measurement($p < 0.01$) in vocal polyp group. However, there was no significant difference($p > 0.05$) in vocal nodule group. Through comparing the results, we obtained the conclusion : The laryngo-microsurgery is the reliable method of management for the vocal polyps, but for the vocal nodules, the laryngo-microsurgery should be selected after other more conservative approaches fail to produce the desired results.

KEY WORDS : Vocal efficiency · Vocal polyp · Vocal nodule.

Introduction

Efficiency, with respect to the physical energy which may be stored, transferred, or transformed by a device, is the ratio of the useful output to its total input(Fay and Goetz, 1984)[3]. As an energy transformer, when the human phonates, the vocal system converts the aerodynamic power provided by the pulmonary system to acoustic power which is transmitted through the vocal tract and is finally measured as the acoustic power radiated from the lips. For this system the total input power, namely aerodynamic power, is defined as the product of tracheal pressure and average glottal airflow, while the useful output for voice production is the acoustic power. According to the definition, vo-cal efficiency(VE) can be calculated as the ratio of acoustic power to aerodynamic power : Vocal efficiency=acoustic power/ average airflow* tracheal pressure(van den Berg[15], 1956 ; Schutte[10], 1980). The vocal efficiency of normal adult's phonation based on this definition found values between 10^{-6} to 10^{-2}(van den Berg[15], 1956 ; Schutte[10], 1980 ; Holmberg et al[4], 1988 ; Titze[14], 1992).

According to the Choi et al's study(1996)[1], when the patient has vocal dysfunction due to either of unilateral vocal fold paralysis or vocal polyps, the efficiency at the vocal fold decreases markedly comparing to that of normal control.

Vocal fold polyps and nodules are by far the most common benign mass lesions of the larynx. Major treatments for them are surgical removal and voice

therapy[6)7)8)9)]. In cases of vocal polyps, there is no argument that surgical removal is the choice of the treatment. However, there is no consensus for the ideal treatment modalities in vocal nodules especially when the nodule is firm and organized in considerable sizes.

In this study, we do surgical removal as the treatment modality for all cases of vocal polyps and vocal nodules. The values of the VE, which was measured before surgery and after 2 months postoperatively, were compared statistically to investigate the effect of the surgery on efficiency of voice production.

Materials and Methods

1. Subjects

20 patients with vocal polyps, 10 patients with vocal nodules and 20 normal subjects participated in the present study. The age and gender distibutions were as Table 1.

In this study, for the sake of convenience, we defined the polyps as a lesion(s) in the middle of the membraneous vocal fold(s), often on the free edge, sessile or pedunculated, and very mobile when pedunculated and defining the nodules as small lesions occurring on both sides of the vocal folds, strictly symmetric on the border of the anterior and middle third of the vocal folds, and usually immobile during phonation. Diagnosis was confirmed by an Otolaryngologist using video-laryngoscopy or video-stroboscopic examination of the patients.

2. Methods

The vocal intensity, fundamental frequency, mean airflow rate and subglottic pressure during phonation of vowel /O/ in a comfortable pitch and loudness level were measured simultaneously using a Nagashima

Table 1. The age and gender distribution of the subjects

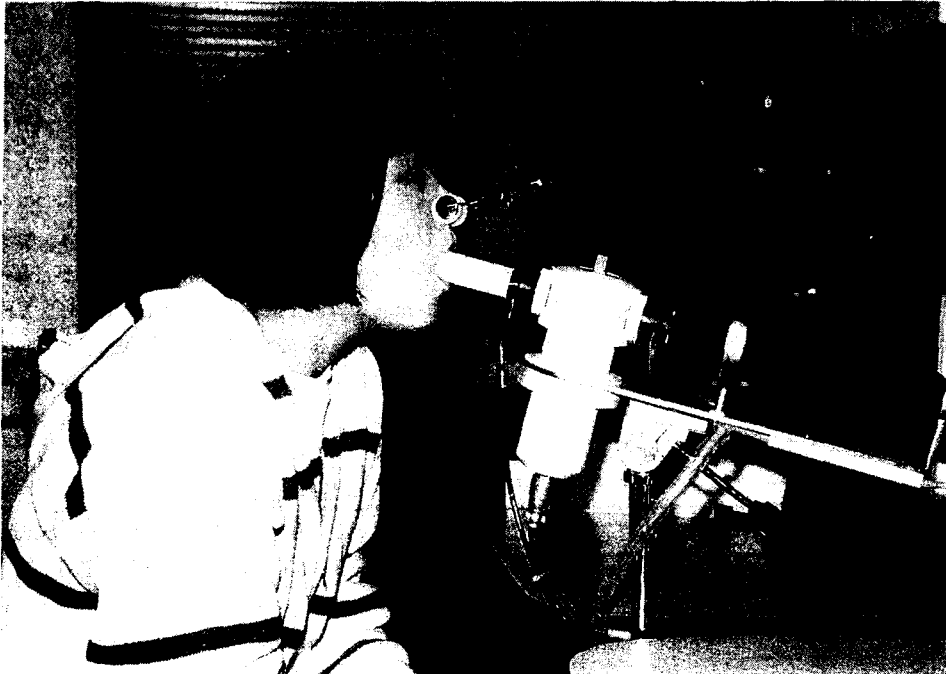|	Total	Gender		Age	
		M	F	Age range	Age mean
Vocal polyps	20	13	7	31 – 64	42.2
Vocal nodules	10	3	7	31 – 51	38.6
normal control	20	14	6	22 – 43	28.4

Phonatory Function Analyzer(model PS 77H)(Fig. 1). Each subject's voice trial was done on two occasions, preoperation and two months postoperation with vocal polyps and nodules, however the normal subjects were done once. All subjects were comfortably seated in a quiet room during all aspects of data collection. The data were obtained from sustained vowel(/O/). The vowel was produced at a comfortable pitch and loudness. Then according to the formula VE could be calculated as below(Fig. 2)[11)] Vocal efficiency(VE) = Acoustic power(watts)/Aerodynamic power(watts) = $4\pi R^2(R=0.3M) \times$ Sound intensity(watts per square meter)/Air flow fate(cubic meters per second) × Subglottic pressure(newtons pr squaremeter).

The data which were collectted preoperatively from the polyps and nodules were statistically compared with those of postop. 2 months' data using paired T-test from Microsoft Excel 5.0 program.

3. Results

1) Vocal efficiency of normal subjects

The maximum vocal efficiency of normal subjects was 1.38×10^{-3}, and the minimum was 0.29×10^{-3}, and the average was 0.6×10^{-3}. The vocal efficiency of the polyps tested preoperatively : the maximum was 0.46×10^{-3}. The vocal efficiency of the polyps tested preoperatively : the maximum was 0.46×10^{-3}, the minimum was 0.02×10^{-3} and the average was 0.17×10^{-3}.

2) Vocal efficiency of polyp patients

In the postoperative evaluation in polyp group, the maximum of vocal efficiency was 0.90×10^{-3}, the minimum was 0.1×10^{-3} and the average was 0.47×10^{-3}(Table 2).

3) Vocal efficiency of nodule patients

The maximum was 0.75×10^{-3}, the minimum was 0.03×10^{-3} and the average was 0.39×10^{-3} before surgical treatment. After the surgery, the maximum of vocal efficiency was 1.24×10^{-3} the minimum was 0.01×10^{-3} and the average was 0.4×10^{-3}(Table 3).

4) The results of the postoperative rating for

Fig. 1. Measurement of vocal efficiency.

Acoustic power=4×3.14×R²×sound intensity

$$\text{Vocal efficiency} = \frac{\text{Acoustic power, watts}}{\text{Aerodynamic power, watts}}$$

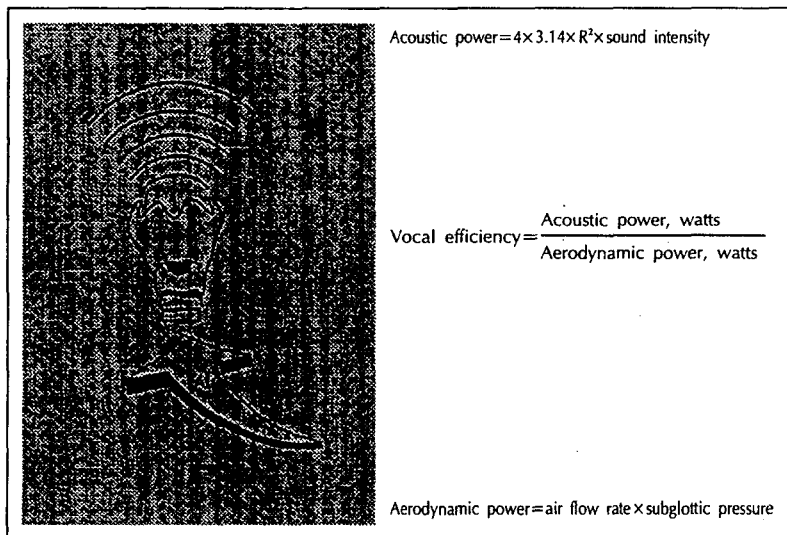Aerodynamic power=air flow rate×subglottic pressure

Fig. 2. Vocal efficiency is ratio of acoustic power radiating from larynx to aero-
dynamic power delivered to larynx.

each group of subjects were as Table 4.

In polyp group, VE was improved in 85% after sur-
gery, however, in vocal nodule group, VE was im-
proved only in 40% of the patients and became worse
in 60%(Table 4).

5) Statistical analysis of the vocal efficiency

The results revealled a significant reciprocal re-
lationship(p<0.01, Table 2) between preoperation
and postoperation with the polyps. It proved that

Table 2. Results of VE of polyps

	Case	Minimum	Maximum	Average
Control	20	0.29×10^{-3}	1.38×10^{-3}	0.6×10^{-3}
Preoperation	20	0.02×10^{-3}	0.46×10^{-3}	0.17×10^{-3}
Postoperation	20	0.1×10^{-3}	0.9×10^{-3}	0.47×10^{-3}

preop. vs. postop. : P=0.003

Table 3. Results of VE of nodules

	Case	Minimum	Maximum	Average
Control	20	0.29×10^{-3}	1.38×10^{-3}	0.6×10^{-3}
Preoperation	10	0.03×10^{-3}	0.75×10^{-3}	0.39×10^{-3}
Postoperation	10	0.01×10^{-3}	1.24×10^{-3}	0.4×10^{-3}

preop. vs.postop. : P=0.48

Table 4. Results of the treatment for the subjects

	Case	Improvement	Unchange	Worse
Polyps	20	17(85%)	1(5%)	2(10%)
Nodules	10	4(40%)	0(0%)	6(60%)

Table 5. P values between disorders and normal subjects

	Polyps		Nodules	
	Preop.	Postop.	Preop.	Postop.
Control	0.0001	0.102	0.006	0.064

there was satisfactory effect with microsurgery approach treating the vocal polyps. But, it showed no significant differential relationship(p>0.05, Table 3) between the pre- and post-treatment with the nodules. It demonstrates that microsurgery management was not the most effectively method for vocal nodules.

4. Discussion

Vocal polyps and nodules are the most common benign lesion of the larynx. It has been well documented that vocal polyps are most frequently observed in middle ages of both sexes(Yamada et al., 1977[16]). Vocal fold nodules, on the other hand, are common in boys and middle aged women[6)9)16]. Hoarseness is the most frequent initial symptom, some patients complain of abnormal dryness or obstructive sensation of the throat and/or cough.

For the polyps, the main treatment is the surgical method and this present data clearly demonstrated it. But, for the vocal nodules, most of the voice thera-

pists prefer to treat the patients by way of voice rest, voice therapy to reduce vocal folds tension during phonation. And some surgeons do surgical removal using either of microinstruments or CO_2 laser. Although textbooks and the literature support the use of voice therapy for vocal nodules, resent surveys suggest that this is not the prevailing practice[7)8]. Fifty percent of the otolaryngologists who responded to a survey by Moran and Pintz felt that surgery or surgery followed by voice therapy was the preferred treatment for adults with vocal nodules[7]. So that, for the vocal nodules there has been no nationwide consensus for the ideal method of treatment so far.

Vocal efficiency was first defined by van den Berg (1956)[15] as the ratio of the acoustic power to the subglottal power and this relation was further studied by Isshiki(1967)[5] through simultaneous recordings of subglottal pressure, air flow rate, and sound pressure level. It is able to reacts directly the function of the larynx and vocal fold. In our studies, the vocal efficiency of normal subjects were between 0.29×10^{-3}(average 0.6×10^{-3}), the vocal polyps were between 0.02×10^{-3} and 0.46×10^{-3}(average 0.17×10^{-3}) and the vocal nodules were between 0.03×10^{-3} and 0.75×10^{-3}(average 0.39×10^{-3}). The results show a significant reciprocal relationship(p<0.05) between the normal control and the preoperative abnormal voice. Postoperative statistical data reveal that there is obvious effects through the surgical treatment on vocal polyps, however, there is no distinctal effects on the vocal nodules.

The present studies demonstrated that the polyps could be removed by the microsurgery as the first selected method of treatment. For the vocal nodules, the results of this study suggest that the microsurgery was not ideal method of management. According to the pathophysiology of vocal nodules, vocal nodules form in response to trauma, that is excessive pressure caused by faulty vocal habits. Removal of the trauma should allow healing and reorganization of the epithelium.

Little is known about the biologic process that forms nodules. However, cellular processes are in-

volved in calluses formed on the vocal folds in response to mechanical stimulation. Simple removal of the hypertrophic tissue is not sufficient if the forces that originally formed the lesion are not removed. Resolution of the calluses occurs without surgical removal, of the inciting trauma is removed and sufficient time is allowed for the resolving process.

Because surgery carries risk of scarring and anesthetic complications, it should be considered only after more conservative approaches fail to produce the desired results.

5. Conclusion

1) The vocal efficiency of vocal polyp shows significant reciprocal relationship between the preoperation and postoperation.

2) The vocal efficiency of vocal nodules did not reveals obvious difference between the preoperation and postoperation.

3) The microsurgery is one of the ideal methods of management for the vocal polyps, but for the vocal nodules, the microsurgery should be selected after other more conservative approaches fail to produce the desired results.

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