Aerodynamic Analysis of Vocal Fold Polyps

*Khalid Hassan Al-Malki, M.D., Ph.D.*

Consultant of Communication Disorders

Communication and Swallowing Disorders Unit (CSDU)

Department of ORL

King Abdul Aziz University Hospital, Riyadh

**Correspondence address:**

Khalid H. Al-Malki

P.O Box 23008

Riyadh, 11426

Saudi Arabia
Abstract

Objective: To evaluate the effect of vocal fold polyps on aerodynamic analysis of the voice.

Material and Method: An experimental controlled prospective study composed of two groups. Group one contained 31 adult patients with vocal fold polyps on either or both vocal folds. Group two was composed of 30 subjects with normal larynges and respiratory systems. Both groups were subjected to aerodynamic analysis using Aerophone II.

Results: Compared to control group, vocal fold polyps caused statistically highly significant increase in: phonation quotient (PQ), mean flow rate (MFR), subglottal pressure ($P_{sub}$), and glottal power (Pg). They caused statistically highly significant decrease in: maximum phonation time (MPT) and glottal resistance (Rg). There were no statistically significant differences in vital capacity (VC) or glottal efficiency (Eg).

Conclusion: Aerodynamic analysis of voice is one of essential investigative tools in assessment of vocal fold polyps.

Key words: vocal fold, polyp, aerodynamics, glottal gap.
**Introduction**

Vocal fold polyps are swellings on the middle third of the membranous part of the vocal fold, often on the free edge, and usually unilateral. They can be sessile or pedunculated, and are very mobile when pedunculated \(^1\). Like other benign vocal fold lesions, the most important cause of vocal fold polyps is vocal abuse and misuse (vocal trauma) \(^2, 3\). They can even occur as a result of a single acute vocal trauma \(^4\). They are seen more commonly in males, particularly in those who engage in intermittent severe voice abuse or who work in noisy environment \(^5\). It is thought that phonotrauma induces relatively major trauma to vocal fold vessels leading to hemorrhage, fibrin exudation, thrombosis, and proliferation of capillaries. Integral repair of the initial damage is then probably hampered by recurrent movements of the lesion during phonation, inducing recurrent capillary trauma as is demonstrated ultrastructurally \(^1\). The pathology is located in the superficial layer of lamina propria \(^6\). The following types can be identified depending on the prevalence of one or the other structural characteristics: fibrous polyps, telangiectatic polyps, and hyaline polyps \(^2\). The patient having vocal fold polyp usually complains of dysphonia (change of voice) with or without voice fatigue symptoms. Aerodynamic analysis of voice is based on the fact that voice
production is essentially an aerodynamic phenomenon, whereby the glottis transforms aerodynamic power into acoustic power. For phonation to take place, both a suitable quantity of air and a suitable air pressure are needed. The aerodynamic forces working at the glottis seem to be responsible for the creation of the sustained vibratory system of the vocal folds \(^{(7, 8)}\). Aerodynamic analysis of voice production includes measurements of airflow, air pressure, and their relationships during phonation. Early investigators found that aerodynamic studies are helpful in etiological classification of voice disorders \(^{(7, 9)}\), while later studies showed that the diagnostic value of aerodynamic measurements is low in identifying the exact etiology, but they may point to a tendency to the “hyperfunction” or “hypofunction” styles of vocal production \(^{(10, 11)}\). However, the main value of aerodynamic measures is to evaluate the degree of vocal dysfunction and to monitor the post-therapeutic changes of voice disorders in the same patient \(^{(12)}\). Some studies showed that aerodynamic studies of the dysphonic voices of vocal fold polyps usually show increased glottal airflow as well as increased subglottal pressure as an attempt to produce phonation in the presence of leaky glottis \(^{(13)}\). The aim of this study is to evaluate the effect of vocal fold polyps on aerodynamic analysis of the voice.
**Materials and Methods**

This is an experimental controlled prospective study composed of two groups. Group one contained 31 adult patients with vocal fold polyps on either or both vocal folds. They were diagnosed using digital videolaryngostroboscopy (Model RLS 9100B, Kay Elemetrics Corp., Lincoln Park, NJ, USA) (*Figure 1*). Group two was composed of 30 subjects with normal larynges and respiratory systems, as confirmed by history, videolaryngoscopic and chest examination. Both groups were subjected to aerodynamic analysis using Aerophone II (Model 6800, Kay Elemetrics Corp., Lincoln Park, NJ, USA) installed to a PC computer (*Figure 2*). The selected airflow type from the option menu of Aerophone II software was the TARGET flow rate because it is believed that this type of flow rate is the most accurate type to have the software determines the airflow rate associated with phonation (*Aerophone II instruction manual p.27, 1995*). All patients in either group were evaluated by the same experimenter.

The following aerodynamic parameters were tested using different “tasks”: (1) **Vital capacity** (VC) which is the maximum volume of air that can be expelled from the lungs following a maximum inspiration. (2) **Maximum phonation time** (MPT) is the longest phonation following maximum inspiration. (3) **Phonation quotient** (PQ) is determined by
dividing VC by MPT. It is computed to reduce the possible bias of supportive respiratory capabilities compensating for poor vocal fold closure \(^{(8)}\). (4) Mean airflow rate (MFR) during vowel production is measured using a pneumotachograph, which consists of a hand-held flowhead connected to a mask within which is placed a fine mesh wire screen in order to create a small resistance to airflow. This resistance results in a pressure difference across the screen that can be measured with a differential pressure transducer. The pressure difference increases with airflow. (5) The mean SPL is the average loudness, in SPL, in a given phonation task. (6) Subglottic pressure \((P_{\text{sub}})\) is obtained by measuring the intra-oral pressure, with a tiny tube inside the mouth, produced during the repeated pronunciation of a voiceless plosive within a nonsense syllable, e.g. /iːpiːpiː/. (7) Glottal aerodynamic input power \((P_g)\) is calculated as \(P_{\text{sub}}\) (during /p/ production) multiplied by MFR (during vowel production). (8) Glottal efficiency \((E_g)\) is expressed as the acoustic output power (mean SPL) divided by the aerodynamic input power \((P_g)\). (9) Glottal resistance \((R_g)\) is calculated as \(P_{\text{sub}}\) divided by MFR. Every patient or subject was asked to perform the following tasks \((\text{Aerophone II instruction manual, 1995})\): [1] Vital Capacity Task: While standing, the patient/subject was asked to inhale as deeply as possible, and then to exhale as fast and as strong as possible. A facemask was used. Three attempts were done using the flowhead F1000, and the
greatest value was taken as the measurement of vital capacity. 

[2] **Maximum Sustained Phonation Task:** The patient/subject was asked to sustain a phonation of the vowel /a/ for as long as possible at a comfortable pitch and loudness after a maximum inspiration. Pitch was set to be as close as possible to the expected for the subject’s gender and age (e.g., 128 Hz for an adult male, and 256 Hz for an adult female). SPL was set on 50-100 dB. Three attempts were done using the flowhead F300 and a facemask. The greatest value was taken as the measurement of MPT \(^{(14)}\). Mean airflow rate for maximum sustained phonation (MFR), PQ, and mean SPL were calculated also under this task. 

[3] **I:PI:PI: Task:** Using the flowhead F300 and a facemask with a tiny tube inside the mouth, the patient/subject was asked to repeat the syllable /i:pi:pi:/ several times at a comfortable pitch and loudness. SPL was set on 50-100 dB. Before the start of the recording, the patient/subject practiced this task coached by the experimenter. This task permitted calculation of \(P_{sub}\), \(P_g\), \(E_g\), and \(R_g\). These measures are computed automatically by Aerophone II. The differences in readings calculated by Aerophone II in the three above-mentioned tasks between the two groups were examined using the t-test of independent samples.
Results

The study comprised of two groups. Group I was composed of 31 vocal fold polyp patients; 20 males (65 %) and 11 females (35 %). Mean age was 40.7 ± 10.6 years (range, 26 – 60 years). Sixteen patients (52 %) had right-sided polyps, 11 patients (35 %) had left-sided polyps, and the remaining 4 patients (13 %) had bilateral vocal fold polyps. Group II comprised 30 normal adult subjects; 18 males (60 %) and 12 females (40 %). Mean age was 35.6 ± 12.9 years (range, 15 – 65 years). The mean values and standard deviations for the aerodynamic variables, as well as the results of the t test of both groups, are presented in table 1. As can be seen, the means of VC for both groups were virtually the same. The difference between the two groups was statistically insignificant. The mean MPT for group I was less than the control group (group II). The difference was statistically highly significant. The mean PQ and the mean MFR for group I showed higher recordings than group II, with highly significant statistical differences. The mean SPL did not reveal any significant statistical difference between the two groups. The mean P_{sub} and the mean P_g for group I showed higher recordings than the control group (group II). The differences were statistically highly significant. The mean E_g did not demonstrate any significant statistical difference between the two groups. R_g showed lower reading in group I compared to group II. The difference was statically highly significant.
Discussion

Since the vital capacity (VC) reflects mainly lung function, it was expected that there will be no statistical difference between the patients (group I) and the control subjects (group II). On the contrary, maximum phonation time (MPT) was much less in the patients' group, because vocal fold polyps hinder complete coaptation of vocal folds during phonation. This leads to formation of phonatory glottal gap, causing "air leak" during phonation. As a consequence, the maximum duration the patient can phonate is expected to decrease in presence of vocal fold polyps. Since phonation quotient (PQ) is determined by dividing VC by MPT, and since there was statistically highly significant decrease of MPT (the denominator of the above-mentioned equation) between the two groups, it is expected for PQ to show a highly significant increase in group I as compared to group II. The phonatory glottal gap that results from vocal fold polyp leads to air leak, as has been explained. This can explain the increase in mean flow rate (MFR) in group I compared to group II. Vocal intensity (and its correlate, sound pressure level (SPL)) is determined mainly by the expiratory airflow in presence of adducted vocal folds \(^{(15)}\). Since vocal fold polyps do not alter pulmonary function, and since the glottal gap caused by vocal fold polyp is not large enough to waste expiratory airflow, SPL was not expected to show significant differences between the two groups. Subglottal pressure (P_{sub}) represents
the energy immediately available for creation of the acoustic signals (16). Since vocal fold polyp hinders proper acoustic signals because of the glottal air leak, the patient with vocal fold polyp tries to "compensate” for this by increasing \( P_{\text{sub}} \). This can explain the statistically highly significant increase in \( P_{\text{sub}} \) in group I compared to group II. The increase in MFR, PQ, and \( P_{\text{sub}} \); and the associated decrease in MPT due to vocal fold polyps are in agreement with the findings documented by other studies (7, 13).

Glottal aerodynamic input power (Pg) is calculated by the multiplication of subglottal pressure (\( P_{\text{sub}} \)) by mean flow rate (MFR). Since the latter two parameters showed statistically highly significant increase when comparing both groups, it is expected that glottal power (Pg) will show the same. Glottal efficiency (Eg) is determined by dividing SPL by Pg. Absence of statistical difference between the two groups in Eg can be attributed to the absence of statistical difference between the two groups in SPL, although Pg (the denominator of the above-mentioned equation) showed statistically highly significant increase when comparing both groups. Absence of statistical difference between the two groups in Eg may indicate that group I patients can still maintain an "efficient" glottis in spite of presence of vocal fold polyps. This can be explained by the fact that most of group I patients had relatively small polyps. Glottal resistance (Rg) is calculated by dividing \( P_{\text{sub}} \) by MFR. As had been
explained, $P_{sub}$ and MFR showed statistically highly significant increase in group I compared to group I. But, the statistically highly significant decrease in $R_g$ can be attributed to the phonatory glottal gap caused by vocal fold polyp, leading to a decrease in the resistance of the glottis. It can be also attributed to the possibility that the increase in MFR was much higher than that of $P_{sub}$. 
Conclusion

According to the findings of the current study, and compared to the control group, vocal fold polyps caused statistically highly significant increase in: phonation quotient (PQ), mean flow rate (MFR), subglottal pressure (P_{sub}), and glottal power (Pg). They also caused statistically highly significant decrease in: maximum phonation time (MPT) and glottal resistance (Rg). There were no statistically significant differences in vital capacity (VC) or glottal efficiency (Eg).
References


