

Acoustic Characteristics in Epiglottic Cyst

*YeonWoo Lee, *GeunHyo Kim, †SooGeun Wang, ‡JeonYeob Jang, †Wonjae Cha, §HongSik Choi, and ¶HyangHee Kim, *†Busan, ‡Suwon, and §¶Seoul, South Korea

Summary: Objective: The purpose of this study was to analyze the acoustic characteristics associated with alternation deformation of the vocal tract due to large epiglottic cyst, and to confirm the relation between the anatomical change and resonant function of the vocal tract.

Methods: Eight men with epiglottic cyst were enrolled in this study. The jitter, shimmer, noise-to-harmonic ratio, and first two formants were analyzed in vowels /a:/, /e:/, /i:/, /o:/, and /u:/. These values were analyzed before and after laryngeal microsurgery.

Results: The F1 value of /a:/ was significantly raised after surgery. Significant differences of formant frequencies in other vowels, jitter, shimmer, and noise-to-harmonic ratio were not presented.

Conclusion: The results of this study could be used to analyze changes in the resonance of vocal tracts due to the epiglottic cysts.

Key Words: Vocal tract—Epiglottic cyst—Vowel—Formant—F1—F2—Jitter—Shimmer—Noise-to-harmonic ratio.

INTRODUCTION

Epiglottic cyst is a disease belonging to the laryngeal cyst such as epiglottic vallicular cyst, aryepiglottic cyst, and ventricular fold cyst. Epiglottic cyst is an acquired disease,¹ but occasionally it can occur congenitally.² Epiglottic cyst is a benign tumor contributing about 4.3%–6.1% of all laryngeal benign tumors.³ Among the epiglottic cysts, mucosal retention cyst is characterized by frequent recurrence, and epidermal cyst is characterized by a large size. Epiglottic cysts could be diagnosed through indirect laryngoscopy or laryngeal endoscopic examination.⁴

The management of epiglottic cyst is dependent on the size of the cyst. Most cysts can be removed using forceps or lasers through direct laryngoscopy. In case of large-sized cysts, lateral pharyngotomy or laryngofissure approach is used for complete removal of the cyst. If complete removal is not implemented during the operation, the epiglottic cysts may recur. Thus, it is recommended to remove completely the cysts during surgery.⁵ Chung et al⁵ described a clinical syndrome of epiglottic cysts in infants consisting of the respiratory difficulties, stridor, and tachypnea. Older patients with epiglottic cysts may have a foreign-body sensation and pain in the throat, dysphagia, and acoustic changes in voice. The acoustic changes, termed “cul-de-sac resonance,” “muffled voice,” or “hot potato voice,” and hoarseness, might be produced.⁶ These acoustic changes are characterized by a

pharyngeal focused resonance and obstructive oral outflow of air resulting in acoustic changes.^{7,8}

The anatomical change of the vocal tract is closely related with acoustic changes, and it is caused by the changing shape of vocal tracts brought about by such factors as tongue cancer,⁹ tonsillitis,¹⁰ large tonsil,¹¹ as well as age and gender.¹² There are many studies of normative formant data, as well as extensive work on acoustic analysis according to the transformation of the vocal tract's structures. Although the changing shape of the vocal tracts may affect acoustic characteristics, research on how epiglottic cysts affect the structure of the vocal tract and its acoustic characteristics remain scarce.

Thus, we analyzed the acoustic changes due to epiglottic cysts and discussed the acoustic features in relation to structure and function of vocal tract. This study would be used to characterize the acoustic characteristics of the epiglottic cysts.

METHODS AND MATERIALS

Materials

This study was a retrospective study and the Institutional Review Board of Pusan National University Hospital approved this study. All subjects were diagnosed with epiglottic cyst from May 2015 and August 2016 in Pusan National University Hospital. They did not have neurological diseases, mental disorders, dysarthria, and other laryngeal diseases. All patients underwent laryngeal microsurgery within 1 month after diagnosis. A total of 11 patients (9 males and 2 females) were diagnosed with epiglottic cysts. Of the 11 patients, one man and one woman did not visit the hospital after surgery, and one woman could not perform the voice analysis because of pain in the throat. Finally, this study was conducted based on the voice samples of eight male patients.

Methods

The recording process was performed using the *Computerized Speech Lab* (CSL model 4500, KayPentax, Lincoln

Accepted for publication January 25, 2018.

From the *Department of Otorhinolaryngology-Head and Neck Surgery and Biomedical Research Institute, Pusan National University Hospital, Busan, South Korea; †Department of Otorhinolaryngology-Head and Neck Surgery, Pusan National University School of Medicine, Busan, South Korea; ‡Department of Otolaryngology, Ajou University School of Medicine, Suwon, South Korea; §Department of Otorhinolaryngology, Institute of Logopedics & Phoniatrics, Yonsei University College of Medicine, Gangnam Severance Hospital, Seoul, South Korea; and the ¶Department of Rehabilitation Medicine and Research Institute of Rehabilitation Medicine, Yonsei University College of Medicine, Seoul, South Korea.

Address correspondence and reprint requests to HyangHee Kim, Department of Rehabilitation Medicine and Research Institute of Rehabilitation Medicine, Yonsei University College of Medicine, 50-1 Yonsei-Ro, Seodaemun-Gu, Seoul, 03722, Korea. E-mail: h.kim@yonsei.ac.kr

Journal of Voice, Vol. 33, No. 4, pp. 497–500
0892-1997

© 2018 The Voice Foundation. Published by Elsevier B.V. All rights reserved.
<https://doi.org/10.1016/j.jvoice.2018.01.023>

Park, NJ) with unidirectional dynamic microphone (Shure SM48, Shure Inc, Niles, IL) in a soundproof laboratory (11,025 Hz sampling rate, 16 bit). The microphone was placed at approximately 15 cm from the speaker's mouth. To minimize the influence noise, the microphone was placed at an angle of approximately 15°. Clinicians performed voice analysis on all patients the day before LMS. After 7~10 days of surgery, patients visited the hospital and clinicians performed voice analysis on all patients. Fundamental frequency (F0), jitter, shimmer, noise-to-harmonic ratio (NHR), and the first two formants (F1 and F2) were analyzed. The task of voice analysis was phonating five vowels (/a:/, /e:/, /i:/, /o:/, and /u:/) for three times and phonating for 5 seconds each time at comfortable pitch and loudness. Before recording, the clinician explained the task to the subjects. After understanding and practicing the task, the voice analysis was implemented. We compared preoperative and postoperative voices for analyzing the differences of F0, jitter, shimmer, NHR, and F1 and F2 of each vowel.

For analyzing the values of F0, jitter, shimmer, and NHR, we selected the middle 3-second segment in vowel /a:/ . For analyzing values of the first two formants, the selected 3-second segments were used in the five vowels. According to the criteria proposed by Kang et al,¹⁴ the first two formants values were obtained at the portion where the stable pulse signal was presented and the formants, pitch, and sound intensity were shown horizontally.

Statistical analysis

We used *SPSS 18.0 software* (Statistical Product and Service Solution, Version 18.0, Chicago, IL). At first, Kolmogorov-Smirnov test was used to assess the test of normality. After the assessment of test of normality, statistical analysis was implemented by comparing mean values of each preoperative and postoperative F0, jitter, shimmer, NHR, and F1

and F2 of each vowel using paired *t* test. Statistical analysis was performed with a significance level of 0.01 to reduce the likelihood of false positives due to the small number of patients.

RESULTS

Subject characteristics

The information related to characteristics of epiglottic cysts in patients, clinical symptoms, and clinician's perceptual assessments on the patients' voice were described in [Table 1](#). Eight patients were enrolled in this study. All patients were male, mean age was 59 years old, and standard deviation (SD) of mean age was 6.8. All patients felt a foreign-body sensation and some patients complained of throat pain, voice changes, and swallowing problems. In the clinician's auditory perceptual assessments, five patients produced hot potato voice or muffled voice and six patients produced hoarse voice. In the result of flexible endoscopic examination, the movements of vocal cords were intact.

Fundamental frequency, jitter, shimmer, noise-to-harmonic ratio

The mean values and SDs for F0, jitter, shimmer, and NHR are presented in [Table 2](#). There were no significant differences between preoperative and postoperative results.

Comparison of pre- and postoperative first formant (F1)

The mean values and SDs for preoperative and postoperative F1 are presented in [Table 3](#). Of these, the F1 value for vowel /a:/ was significantly raised after surgery (preoperative: 590.4 ± 62.7 Hz, postoperative: 699.9 ± 48.4 Hz, $P < 0.01$). However, in other vowels, statistically significant differences were not revealed.

TABLE 1.
The Characteristics of Epiglottic Cysts in Patients, Clinical Symptoms, and Clinician's Perceptual Assessments of the Voice

Patient	Age/Sex	Side	Size	Presenting Symptoms	Perceptual Assessments	Vocal Folds Movements
1	58/Male	Median	35 mm	Foreign-body sensation and dysphagia	Hot potato voice	Intact
2	68/Male	Median	18 mm	Foreign-body sensation	Hot potato voice	Intact
3	55/Male	Left	25 mm	Foreign-body sensation	Hoarseness	Intact
4	66/Male	Right	16 mm	Foreign-body sensation	Hot potato voice and hoarseness	Intact
5	47/Male	Left	50 mm	Foreign-body sensation and respiratory difficulty	Hoarseness	Intact
6	55/Male	Left	14 mm	Foreign-body sensation and voice change	Hot potato voice and hoarseness	Intact
7	63/Male	Right	21 mm	Foreign-body sensation and voice change	Hoarseness	Intact
8	60/Male	Left	16 mm	Foreign-body sensation, throat pain, and dysphagia	Hot potato voice and hoarseness	Intact

TABLE 2.
Pre- and Postoperative Values of F0, Jitter, Shimmer, and NHR (mean \pm SD, N = 8) for Patients With Epiglottic Cysts Who Underwent Laryngeal Microsurgery

Acoustic Parameters	Preoperative (Mean \pm SD)	Postoperative (Mean \pm SD)	P Value
Fundamental frequency (F0) (Hz)	114.00 \pm 9.18	112.38 \pm 9.64	0.311
Jitter (%)	0.714 \pm 0.44	0.680 \pm 0.38	0.276
Shimmer (%)	3.755 \pm 1.47	3.698 \pm 1.41	0.191
Noise-to-harmonic ratio (NHR)	0.139 \pm 0.02	0.137 \pm 0.02	0.596

TABLE 3.
Pre- and Postoperative Values of First Formant Frequency (mean \pm SD, N = 8) for Patients With Epiglottic Cysts Who Underwent Laryngeal Microsurgery

Vowel	Speech Parameters (Hz)		P Value
	Preoperative (Mean \pm SD)	Postoperative (Mean \pm SD)	
/a:/	590.4 \pm 62.7	699.9 \pm 48.4	$P < 0.01$
/e:/	455.8 \pm 53.9	459.4 \pm 42.6	0.884
/i:/	277.9 \pm 36.0	285.9 \pm 37.1	0.652
/o:/	385.5 \pm 56.6	400.5 \pm 62.9	0.458
/u:/	300.9 \pm 25.8	327.4 \pm 30.0	0.141

$P < 0.01$ represents the significant statistical analysis by comparing mean values of each preoperative and postoperative formant of vowels.

Comparison of pre- and postoperative second formant (F2)

The mean values and SD for preoperative and postoperative F2 are presented in Table 4. There were no significant differences in all vowels.

DISCUSSION

Changes of the vocal tract's structures are assumed to affect the acoustic characteristics on voice. In previous studies, changes of acoustic characteristics due to tonsillitis,

peritonsillitis,¹⁵ tonsillar hypertrophy,^{11,16} and obstructive sleep apnea¹³ were reported. Chuma et al¹⁷ reported the effects of tonsillectomy or adenoidectomy on vocal function. They found that tonsillectomy or adenoidectomy had little impact on acoustic or perceptual features of vocal functions during the 15 weeks after surgery. Mora et al¹⁶ reported the effects of adenotonsillectomy on speech spectrum in children. They found that various acoustic parameters were improved after adenotonsillectomy. Bhutta et al¹⁵ reported that dyskinesia of levator veli palatini due to peritonsillitis affected the vocal resonator and thus, the acoustic features might be changed. However, the effects of epiglottic cysts on acoustic features in the voice have received little interest, with wide recognition that the acoustic changes labeled cul-de-sac resonance or hot potato voice occur. In this study, the authors analyzed the acoustic changes due to epiglottic cysts and discussed the acoustic features in relation to structure and function of vocal tract.

The value of first formant is decreased in the high vowels and varies according to height of tongue, degree of jaw opening, and area of pharyngeal cavity.¹⁸ The value of second formant is increased in the anterior vowels and varies according to a degree of anteriority in tongue.¹⁸ The first two formants determine the actual vowel produced.¹⁵

In this study, the F1 value for vowel /a:/ was significantly raised after surgery. For the articulation of /a:/, the value of F1 is relatively high because the pharyngeal cavity is short and narrow, created by depression of the mandible and of the tongue. However, the value of F2 is relatively low because the oropharyngeal cavity is large.¹⁵ The epiglottis is adjacent to the base of tongue and the epiglottic cysts mainly occur on the lingual side of the epiglottis.⁵ Considering this, the results of this study suggested that when pronouncing the vowel /a/, the backward movements of the tongue contracting the pharyngeal cavity might be interrupted by the epiglottic cyst, thus the narrowing pharyngeal cavity might not be sufficiently formed. For the F2 for articulation of vowel /a:/, the significant difference was not found. This meant that epiglottic cysts might not affect the F2, which is more affected by the degree of anteriority in tongue in oral cavity.¹⁵

In this study, there were no significant differences on formant frequency changes of other vowels except for the values of F1 of /a:/. For the articulation of /o:/ and /u:/, the most important change of the vocal tract is its elongation by

TABLE 4.
Pre- and Postoperative Values of Second Formant Frequency (mean \pm SD, N = 8) for Patients With Epiglottic Cysts Who Underwent Laryngeal Microsurgery

Vowel	Speech Parameters (Hz)		P Value
	Preoperative (Mean \pm SD)	Postoperative (Mean \pm SD)	
/a:/	1055.8 \pm 48.6	1086.6 \pm 60.2	0.027
/e:/	1629.1 \pm 110.9	1670.8 \pm 113.1	0.096
/i:/	1944.1 \pm 117.5	2013.5 \pm 220.3	0.841
/o:/	728.5 \pm 63.1	744.6 \pm 69.9	0.487
/u:/	751.3 \pm 85.1	765.5 \pm 104.4	0.364

protrusion of the lips.¹⁵ When pronouncing these vowels, the formant frequencies are consistently lowered as the length of the vocal tract is extended. Vowels /i:/ and /e:/ belong to the front vowels.¹⁸ Because the location of epiglottic cysts is in the back of tongue, the front movement of the tongue might not be interrupted by the epiglottic cyst.

There were no significant differences of F0, jitter, shimmer, NHR. Mora et al¹⁶ mentioned that after the adenotonsillectomy in children, the acoustic parameters such as F0, jitter, shimmer, NHR were improved by the resonance changes in nasopharynx, oral cavities, and nasal cavities. Change of nasalance affects the number of vocal cord vibrations per second,¹⁹ regularities of pitch and amplitude included in voice signal, and the ratio of noise included in voice signals.¹⁶ They reported that in children with enlarged tonsils and hypertrophic adenoids, tonsillar or adenoidal tissue might obstruct the supraglottic airway. This particular vocal tract shape produced an augmentation of vocal tract inertance and resistance that could interfere with the speaker's ability to produce a regular voice. The differences between the previous study and the present study were the location of the lesion, relative size of disease, and the age of the subjects involved in the study. Unlike the location of the adenoids and tonsils, the position of the epiglottis is lower; thus, the nasalance related to the velopharyngeal valve might not be relatively less impacted by the epiglottic cyst. In terms of size of disease, because the subjects in the previous study were children, their vocal tracts were relatively small and narrow, and thus, the size effect of disease on resonance was larger than that of adults. Primarily, when the previous study is compared with the present study, the length and the shape of the vocal tract are different because in the previous study, the subjects were children; thus, the acoustic characteristics might be different from those of adults.

In this study, the acoustic characteristics due to the epiglottic cysts were quantitatively analyzed. Although researches on acoustic analysis were lacking in patients with epiglottic cysts, we confirmed the changes of resonances caused by the epiglottic cysts. It is also important to recognize that in certain individuals using their voices professionally, subtle acoustic changes in voices may have greater impact both psychologically and vocationally. For those individuals, it is necessary to consider surgical planning and counseling.

We did not measure the cross-sectional area of vocal tract. A future study on including direct measurement of the cross-sectional area in vocal tract and assessment of the function of articulators and formant analysis will need to be done. Also, researches on the variance of resonance according to the size and location of epiglottic cysts will need to be done.

CONCLUSION

In patients with epiglottic cysts, the F1 value for vowel /a:/ was significantly raised after surgery because of the interruption of the tongue's backward movements. However, other acoustic parameters such as F0, jitter, shimmer, NHR were not significantly changed. The results of this study will be utilized for the study on acoustic change due to epiglottic cysts.

REFERENCES

1. Newman BH, Tax JB, Laker HI. Laryngeal cysts in adults: a clinicopathologic study of 20 cases. *Am J Clin Pathol.* 1984;81:715–720.
2. Khashu M, Osiovič H, Kozak F, et al. Congenital epiglottic cyst presenting with severe airway obstruction at birth. *J Perinatol.* 2006;26:71–72.
3. Luo C-M, Yang S-W, Chen T-A. Treatment of wide-based epiglottic cyst by microdebrider. *Med Devices (Auckl).* 2009;2:41.
4. Arens C, Glanz H, Kleinsasser O. Clinical and morphological aspects of laryngeal cysts. *Eur Arch Otorhinolaryngol.* 1997;254:430–436.
5. Chung PS, Chung YW, Park SJ, et al. A clinicopathologic study of epiglottic and vallecular cysts. *Korean J Otolaryngol Head Neck Surg.* 2004;47:157–160.
6. Chandrakala S, Bharwaj N, Mohammadi K. Stridor in epiglottic cyst: a rare presentation. *Int J Head Neck Surg.* 2013;4:110–111.
7. Lenden JM, Flipsen P. Prosody and voice characteristics of children with cochlear implants. *J Commun Disord.* 2007;40:66–81.
8. Pigott R. Velopharyngeal (speech) disorder (VP (S) D) without overt cleft palate. *Br J Plast Surg.* 1994;47:223–229.
9. Kazi R, Prasad VM, Kanagalingam J, et al. Analysis of formant frequencies in patients with oral or oropharyngeal cancers treated by glossectomy. *Int J Lang Commun Disord.* 2007;42:521–532.
10. Shoemaker M, Lampe RM, Weir MR. Peritonsillitis: abscess or cellulitis? *Pediatr Infect Dis J.* 1986;5:435–438.
11. İlk HG, Eroğul O, Satar B, et al. Effects of tonsillectomy on speech spectrum. *J Voice.* 2002;16:580–586.
12. Kim Y-S, Kim KH, Kim JY, et al. A study on the formant comparison of Korean monophthongs according to age and gender—a survey on patients in oriental hospitals. *J Korean Soc Speech Sci.* 2013;5:73–80.
13. Robb M, Yates J, Morgan E. Vocal tract resonance characteristics of adults with obstructive sleep apnea. *Acta Otolaryngol.* 1997;117:760–763.
14. Kang Y, Park S, Seong C. Articulation characteristics of patients with idiopathic Parkinson's disease and normal-aging group: articulatory rate & acoustic vowel space. *J Speech Hear Disord.* 2009;18:115–135.
15. Bhutta MF, Worley GA, Harries ML. “Hot potato voice” in peritonsillitis: a misnomer. *J Voice.* 2006;20:616–622.
16. Mora R, Crippa B, Dellepiane M, et al. Effects of adenotonsillectomy on speech spectrum in children. *Int J Pediatr Otorhinolaryngol.* 2007;71:1299–1304.
17. Chuma AV, Cacace AT, Rosen R, et al. Effects of tonsillectomy and/or adenoidectomy on vocal function: laryngeal, supralaryngeal and perceptual characteristics. *Int J Pediatr Otorhinolaryngol.* 1999;47:1–9.
18. Kang Y, Yoon K-C, Lee H-S, et al. A comparison of parameters of acoustic vowel space in patients with Parkinson's disease. *J Korean Soc Speech Sci.* 2010;2:185–192.
19. Van Lierde KM, Wuyts FL, Bodt MD, et al. Age-related patterns of nasal resonance in normal Flemish children and young adults. *Scand J Plast Reconstr Surg Hand Surg.* 2003;37:344–350.