



HAL
open science

Multidimensional Voice Quality Evaluation After Transoral CO2 Laser Cordectomy: A Prospective Study

Yaniv Hamzany, Lise Crevier-Buchman, Jérôme René Lechien, Gideon Y. Bachar, Daniel F. Brasnu, Stéphane Hans

► **To cite this version:**

Yaniv Hamzany, Lise Crevier-Buchman, Jérôme René Lechien, Gideon Y. Bachar, Daniel F. Brasnu, et al.. Multidimensional Voice Quality Evaluation After Transoral CO2 Laser Cordectomy: A Prospective Study. Ear Nose and Throat Journal, 2021, 100 (1_suppl), pp.27S-32S. 10.1177/0145561320906328 . hal-03141467

HAL Id: hal-03141467

<https://hal.science/hal-03141467>

Submitted on 24 Feb 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

Multidimensional Voice Quality Evaluation After Transoral CO₂ Laser Cordectomy: A Prospective Study

Ear, Nose & Throat Journal
2021, Vol. 100(1S) 27S–32S
© The Author(s) 2020
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/0145561320906328
journals.sagepub.com/home/ear



Yaniv Hamzany, MD¹, Lise Crevier-Buchman, MD, PhD², Jérôme R. Lechien, MD, PhD, MS^{2,3} , Gideon Bachar, MD¹, Daniel Brasnu, MD, PhD⁴, and Stéphane Hans, MD, PhD²

Abstract

Objective: To investigate voice quality changes of patients treated by transoral laser cordectomy (TLC) for early glottic cancer according to the type of cordectomies. **Methods:** A total of 164 consecutive male patients with an early glottic cancer were prospectively recruited from the Department of Otolaryngology—Head and Neck Surgery of the Georges Pompidou European Hospital. Depending on the tumor characteristics, patients benefited from type I to VI CO₂ cordectomy regarding the European Laryngological Society classification. The following voice quality outcomes were pre- to postoperatively assessed: voice handicap index (VHI), perceptual grade of dysphonia, roughness, breathiness, maximum phonation time, and acoustic parameters. **Results:** Fifty-five patients with Tis, T1, or T2 vocal fold cancer completed the study (mean age: 61.7 years). Of these patients, 34 and 21 composed group 1 (types I–III TLC) and group 2 (types IV–VI TLC), respectively. Voice handicap index, grade of dysphonia, and breathiness significantly improved from pre- to 3- and 6-month posttreatment in group 1. In group 2, only VHI significantly improved from pre- to 3- and 6-month posttreatment. Acoustic and aerodynamic measurements did not change throughout the postoperative course. Patients with types I to III TLC exhibited better postoperative voice outcomes compared to those treated by types IV to VI TLC. **Conclusion:** Irrespective to the types of TLC, the subjective voice quality of patients treated by CO₂ laser cordectomy for early glottic cancer significantly improved from pre- to 3- and 6-month posttreatment. The usefulness of aerodynamic and acoustic measurements as postoperative outcomes of voice quality changes remain controversial and require future studies considering multidimensional assessment of voice.

Keywords

larynx, laryngeal, cancer, laser, CO₂, cordectomy, voice, assessment

Introduction

The first report of transoral laser cordectomy (TLC) for early stage glottic carcinoma was published by Strong¹ in 1975. Since then, the technique evolved and it is currently worldwide used.^{2–4} Transoral laser cordectomy exhibited lower morbidity, similar survival, and better patient postoperative functional outcomes than conventional surgical approaches. Nowadays, radiation and TLC are considered as the standard therapeutic approaches for early glottic cancer.^{5,6} Clinical studies reported that radiation is associated with similar survival outcomes compared with surgery, but the superiority of radiation over TLC about the voice quality assessment is still controversial.^{7,8}

To date, a few studies investigated voice quality evolution from pre- to post-TLC therapy.^{9–14} Overall, there was an important heterogeneity between studies about the pre- to

¹ Department of Otolaryngology—Head and Neck Surgery, Rabin Medical Center, Petach Tikva and Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel

² Department of Otolaryngology—Head and Neck Surgery, Foch Hospital, School of Medicine, UFR Simone Veil, Université Versailles Saint-Quentin-en-Yvelines (Paris Saclay University), Paris, France

³ Laryngology Study Group of Young Otolaryngologists of International Federation of Otorhinolaryngological Societies (YO-IFOS), Paris, France

⁴ Department of Otolaryngology—Head Neck Surgery, Fondation A. Rothschild, Paris Descartes University (Sorbonne), Paris, France

Received: January 9, 2020; accepted: January 21, 2020

Corresponding Author:

Jerome R. Lechien, MD, PhD, MS, Department of Otolaryngology—Head and Neck Surgery, Foch Hospital, School of Medicine, UFR Simone Veil, Université Versailles Saint-Quentin en Yvelines (Paris Saclay University), Paris, France.

Email: jerome.lechien@umonts.ac.be



posttreatment evolution of voice quality functional outcomes; the voice quality measurements reaching stability 6 months after TLC. Moreover, the majority of studies were characterized by a limited number of patients, and the use of nonexhaustive voice quality measurements. The consideration of the types of cordectomies was also lacking in the majority of clinical studies.⁹⁻¹⁴ However, the type of cordectomies may have an important impact on voice quality outcomes. In our practice, we observed that limited TLC (type I-III cordectomies) report better functional outcomes than extended TLC (type III-VI). The aim of this study was to investigate voice quality changes of patients treated by TLC for early glottic cancer according to the type of cordectomies.

Materials and Methods

Patients and Setting

A total of 164 consecutive patients with an early glottic cancer were prospectively recruited from the Department of Otolaryngology—Head and Neck Surgery of the Georges Pompidou European Hospital, Paris, France. The following inclusion criteria were considered: male sex (to rule out gender-related voice differences), histologically confirmed early stage tumor,¹⁵ and availability to undergo voice quality assessment postoperatively for the 12-month postoperative period. Patients with previous history of voice disorders or radiation therapy were carefully excluded. The local ethics committee approved the study protocol and the informed consent was obtained for all patients.

Transoral Laser Cordectomy

After adequate laryngeal exposition, the laryngologist carefully reassessed the vocal fold lesion with a rigid 0° or 30° endoscope. A Sharplan CO₂ laser with an AcuSpot micromanipulator (Alternup Medical factory, Tel Aviv, Israel) was used in continuous mode (1-5 W, 270 μm spot sizes, Sharplan Laser, Tel Aviv, Israel) for all patients. Lesions were completely removed (“en bloc” resection) on the basis of the computed tomography-scan features and peroperative visual character of the lesion. The type of cordectomy used depended on the size, the location, and the stage of the lesion. Transoral laser cordectomy was classified according to the European Laryngological Society Classification^{16,17} as subepithelial (type I), subligamental (type II), transmuscular (type III), total (type IV), extended (type Va), and anterior (type VI), encompassing the anterior commissure and anterior part of both vocal folds. None of the patients required tracheotomy. Oral intake was started 24-hour after the surgery. Patients were discharged after 24- or 48-hour hospitalization. A voice rest of 10 days was advised for all patients. Patients received proton pump inhibitors for a 3-month duration to control the impact of laryngopharyngeal reflux on the vocal fold healing.¹⁸

Note that 4 patients underwent a “second look” procedure, which revealed in situ carcinoma (n = 1) and granulation tissue

(n = 3). For these patients, the time of voice quality evaluation was adjusted in relation to their last surgery.

Multidimensional Voice Quality Analysis

Patients benefited from videolaryngostroboscopy, subjective and objective voice quality assessments at baseline (preoperative time), 3-, 6- and 12-month post-TLC. The validated French version of the Voice Handicap Index (VHI) was used as patient-reported outcome questionnaire of voice quality.¹⁹ Perceptual voice quality evaluation was based on the blinded rating of Grade, Roughness, and Breathiness (GRB) evaluation system by 2 experienced laryngologists.²⁰ Laryngologists were blinded regarding the type of cordectomy. The perceptual voice quality assessment was based on connected speech and reading text.

The objective voice quality evaluations included aerodynamic (maximum phonation time [MPT]) and acoustic analyses. Patients were recorded during sustained/a/phonation (3 trials) at comfortable intensity and pitch level with a high-quality microphone (AKG 550) placed 4 cm of the mouth. The MPT value consisted of the best duration of 3 trials. Acoustic analysis was conducted through the Multi-Dimensional Voice Program (Kay Elemetrics, Lincoln Park, New Jersey). The following parameters were measured: fundamental frequency (F0), jitter, shimmer, and noise-to-harmonic ratio (NHR). Voice quality outcome changes were evaluated from pre- to postoperative time according to the type of cordectomy (type I-III or IV-VI).

Statistical Analysis

Statistical analysis was performed with Statview software (version 5.0, SAS Institute, Inc). Wilcoxon rank test was used to analyze changes in VHI, GRB, MPT, and acoustic parameters through the 3 to 12-month postoperative course. Mann-Whitney *U* and Friedman tests were used for comparisons between subgroups of patients. A value of $P < .05$ was considered as statistically significant.

Results

Of the 164 patients, 55 completed the study (mean age: 61.7 years, range: 28-85 years). Tumors were classified as Tis in 20 (36.4%) patients, cT1a in 27 (49.1%) patients, cT1b in 3 (5.4%) patients, and cT2 in 5 (9.1%) patients. The following cordectomies were performed: type I (n = 17); type II (n = 10); type III (n = 7); type IV (n = 3); type Va (n = 13), and type VI (n = 5). Thirty-four and 21 patients composed group 1 (types I-III) and group 2 (types IV-VI), respectively (Table 1). Both groups were comparable. There were no other recurrences and no additional treatment (radiation) during the following period. The multidimensional voice quality data from pre- to post-TLC are available in Table 2. The pre- to posttreatment treatment voice quality outcome changes (statistical analyses) of

Table 1. Group Characteristics.

Patient Clinical Data	Type I-III Cordectomy	Type IV-VI Cordectomy
Male patients (n)	34	21
Age (years)		
Mean	63	59
Range	46-85	28-83
Smoking (n)		
Yes	14	12
No	16	7
No data	4	2
T classification (n)		
Tis	19	1
T1a	15	12
T1b	0	3
T2	0	5

Abbreviation: n, number of patients.

groups 1 (types I-III) and 2 (types IV-VI) are described in Tables 3 and 4, respectively.

Overall, VHI, grade of dysphonia and breathiness significantly improved from pre- to 6-month posttreatment in patients who benefited from types I to III TLC (Table 3). Only VHI sub- and total scores significantly improved from pre- to 6-month posttreatment in patients who benefited from types IV to VI TLC (Table 4). Objective voice quality measurements did not improve throughout postoperative period in both groups.

The group comparison revealed that group 1 (types I-III TLC) had better 6-month values of VHI, grade of dysphonia, breathiness, MPT, jitter, shimmer, and NHR compared to group 2 (types IV-VI; Table 5). Similar findings were found for 12-month group comparison at the exception of the grade of dysphonia ($P = .05$) and the NHR mean values ($P = .06$).

Discussion

The dysphonia related to malignant disease is known to significantly impact emotional, physical, functional, and economic aspects of the patient life. The VHI was initially developed for evaluating both patient subjective feeling and disability from their voice disorder.¹⁹ Nowadays, VHI is considered as one the best patient-reported outcome questionnaire for the assessment of voice function.²¹⁻²⁴

The main finding of this study is the usefulness of VHI as postoperative outcome for patients who benefited from cordectomy, irrespective of the type of cordectomies. In other words, patients have considered that the tumor resection through TLC significantly improved their voice; supporting the occurrence of substantial subjective voice quality impairments before TLC. Our results are supported by the longitudinal study of Chu et al¹⁰ who found significant improvements of VHI in a cohort of 25 patients treated by CO₂ cordectomies. Similarly, Keilmann et al,¹³ reported a trend of postoperative improvement of VHI scores in 16 patients who benefited from different types of cordectomies. However, because the VHI is based on

(subjective) self-evaluation, the postoperative score may be influenced by the individual patient's amount of voice use, level of vocal effort, and, particularly, the satisfaction of being successfully treated for a malignant disease.

Moreover, we observed a significant improvement of perceptual dysphonia and breathiness from pre- to 6-month post-treatment in patients treated by types I to III cordectomies. In the same vein, Chu et al and Galletti et al reported significant improvements of perceptual voice quality evaluations throughout the postoperative period.^{10,25} The blinded rating used in this study is a strength for avoiding subjectivity of the rater about the knowledge of the time of the voice recording. The lack of blinded assessment in the previous studies limits us in the literature comparison. Because perceptual voice quality assessments are still subjective and depend on the method, the use of both aerodynamic and acoustic measurements makes particularly sense for exhibiting subtle abnormalities in the vibration process of the vocal folds. Thus, our data did not report significant pre- to post-TLC improvements of aerodynamic and acoustic measurements, corroborating findings of some studies.^{10,12} However, other authors reported significant improvements,^{9,13} or worsening¹¹ of objective voice quality evaluations. The inconsistencies between studies are related to the heterogeneity regarding the patient inclusion criteria (sex, age, history, cofactors), and the methods used for the measurement of acoustic parameters. Thus, previous reports demonstrated that depending on the time interval over which the acoustic parameters are measured, the clinically demonstrated effect of a treatment/posttreatment course may or may not be statistically demonstrated.^{26,27} These data and the discrepancies between our results and those of the literature strengthen the need of standardization of acoustic measurement methods. This point is important for future studies that aim to compare the impact of treatment on voice quality evolution of patients with early glottic cancer. Indeed, the type of treatment may substantially change the biomechanical properties of vocal folds, by the removal of some critical vocal fold layers, such as the Reinke space. Thus, the excision of tumor, margins (eg, a part of the vibrating mucosa), associated with the resection of the vocal ligament or muscle, leads to a fibrosis process and scar formation, which definitively strongly modifies the normal physiologic function of the vocal fold.^{14,28,29} Both aerodynamic and acoustic measurements may be useful for understanding the microfunctioning of the vocal folds. Precisely, the use of subjective and objective voice quality assessments could help the speech pathologist to following patients throughout the voice rehabilitation. In that way, the differences in voice quality outcomes between patients with types I to III cordectomy and those with types IV to VI cordectomy suggest the development/use of different programs of voice rehabilitation considering different approaches of both intensity and frequency of speech therapy sessions.

The main strength of this study is the use of the multidimensional European Laryngological Society protocol, which considers patient-reported outcome questionnaire, perceptual, aerodynamic, and acoustic assessments for the voice quality

Table 2. Pre- to Posttreatment Multidimensional Voice Quality Evolution.

	Multidimensional Voice Results Before and After TLC							
	Pre-TLC		3 Months		6 Months		12 Months	
	Type I-III	Type IV-VI	Type I-III	Type IV-VI	Type I-III	Type IV-VI	Type I-III	Type IV-VI
VHI-functional	9.8	14.4	5.6	11.1	3.2	9.3	3.6	8.7
VHI-emotional	10.4	14.2	4.6	9.9	2.7	6.6	2.3	6.0
VHI-physical	15.4	18.3	9.6	14.6	6.3	12.0	6.2	11.5
VHI-total	35.5	46.9	19.8	35.6	12.3	27.9	11.4	26.2
Grade	1.7	2.2	1.5	2.0	1.1	1.9	1.2	1.7
Roughness	1.6	1.5	1.5	1.4	1.2	1.4	1.1	1.2
Breathiness	1.2	1.6	0.9	1.8	0.6	1.6	0.6	1.4
F0	149.5	136.7	158.8	162.7	141.2	153.3	141.6	146.5
Jitter (%)	2.7	3.2	1.7	4.0	1.8	4.9	1.8	3.4
Shimmer (%)	7.2	7.3	5.2	7.6	5.2	9.0	5.2	7.8
NHR	0.20	0.18	0.20	0.22	0.15	0.24	0.16	0.20
MPT	13.5	12.3	12.2	8.5	12.3	7.6	13.6	7.1

Abbreviations: F0, fundamental frequency; MPT, maximal phonation time; NHR, noise-to-harmonic ratio; TLC, transoral laser cordectomy; VHI, voice handicap index.

Table 3. Longitudinal Comparison of Voice Outcome in Patients After Cordectomy Type I to III.

	3-6-12 Months	3-6 Months	6-12 Months
VHI-functional	<0.0001	<0.0001	NS
VHI-emotional	0.0004	0.003	NS
VHI-physical	0.01	0.0001	NS
VHI-total	0.003	<0.0001	NS
Grade	0.002	0.001	NS
Roughness	NS	NS	NS
Breathiness	0.0007	0.001	NS
F0	NS	NS	NS
Jitter	NS	NS	NS
Shimmer	NS	NS	NS
NHR	NS	NS	NS
MPT	NS	NS	NS

Abbreviations: F0, fundamental frequency; MPT, maximal phonation time; NHR, noise-to-harmonic ratio; NS, non-significant; VHI, voice handicap index.

Table 4. Longitudinal Comparison of Voice Outcome of Patients After Cordectomy Type IV to VI.

	3-6-12 Months	3-6 Months	6-12 Months
VHI-functional	0.002	0.003	NS
VHI-emotional	0.01	0.004	NS
VHI-physical	0.001	0.007	NS
VHI-total	0.002	0.002	NS
Grade	NS	NS	NS
Roughness	NS	NS	NS
Breathiness	NS	NS	NS
F0	NS	NS	NS
Jitter	NS	NS	NS
Shimmer	NS	NS	NS
NHR	NS	NS	NS
MPT	NS	NS	NS

Abbreviations: F0, fundamental frequency; MPT, maximal phonation time; NHR, noise-to-harmonic ratio; NS, non-significant; VHI, voice handicap index.

Table 5. Comparison of Voice Outcome in Patients With Cordectomy Type I-III or IV-VI.

	6 Months	12 Months
VHI-total	0.008	0.005
Grade	0.002	0.05
Roughness	0.33	0.44
Breathiness	<0.0001	0.0002
F0	0.19	0.49
Jitter	<0.0001	0.02
Shimmer	0.0003	0.0006
NHR	0.006	0.06
MPT	0.0002	<0.0001

Abbreviations: F0, fundamental frequency; MPT, maximal phonation time; NHR, noise-to-harmonic ratio; VHI, voice handicap index.

evaluation.³⁰ To our knowledge, only a few studies assessed voice quality of patients treated with TLC with patient-reported outcome questionnaire, perceptual analysis, aerodynamics, and acoustic measurements.^{10,13} Because the subjective and objective voice quality evaluations do not assess similar aspects of voice, it is still important to consider multidimensional assessment for the evaluation of voice quality.

This study has many weaknesses that have to be addressed in future trials. First, we did not record the videolaryngostroboscopic findings, which would provide additional information about the voice quality recovery/changes after treatment. Second, we only considered males in the inclusion of patients, which was related to the fact that sex of patients substantially impacts the assessment and reliability of acoustic measurements. This weakness is balanced by the fact that, in practice, the high majority of patients with head and neck cancer are male. Furthermore, in the future, it would be interesting to conduct similar study for female patients in order to investigate potential gender-related differences, which would be due to vocal fold anatomical and histological differences,³¹ as

well as gender-related differences in the postoperative inflammatory process.³²

Conclusion

The subjective voice quality of patients who benefited from CO₂ laser cordectomy for early glottic cancer significantly improved from pre- to 6-month posttreatment. The improvement was better in types I to III cordectomy patients compared with those who benefited from types IV to VI cordectomy. The VHI is the most indicative tool of voice changes. Future studies are needed to investigate the usefulness of subjective and objective voice quality evaluations in the postoperative course of patients operated for early glottic cancer.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Jérôme R. Lechien  <https://orcid.org/0000-0002-0845-0845>

References

- Strong MS. Laser excision of carcinoma of the larynx. *Laryngoscope*. 1975;85(8):1286-1289.
- Ossoff RH, Sisson GA, Shapshay SM. Endoscopic management of selected early vocal cord carcinoma. *Ann Otol Rhinol Laryngol*. 1985;94(6 pt 1):560-564.
- Wetmore SJ, Key JM, Suen JY. Laser therapy for T1 glottic carcinoma of the larynx. *Arch Otolaryngol Head Neck Surg*. 1986;112(8):853-855.
- Steiner W. Results of curative laser microsurgery of laryngeal carcinomas. *Am J Otolaryngol*. 1993;14(2):116-121.
- Silver CE, Beitler JJ, Shaha AR, Rinaldo A, Ferlito A. Current trends in initial management of laryngeal cancer: the declining use of open surgery. *Eur Arch Otorhinolaryngol*. 2009;266(9):1333-1352.
- Hartl DM, Ferlito A, Brasnu DF, et al. Evidence-based review of treatment options for patients with glottic cancer. *Head Neck*. 2011;33(11):1638-1648.
- Eksteen EC, Rieger J, Nesbitt M, Seikaly H. Comparison of voice characteristics following three different methods of treatment for laryngeal cancer. *J Otolaryngol*. 2003;32(4):250-253.
- Rosier JF, Grégoire V, Counou H, et al. Comparison of external radiotherapy, laser microsurgery and partial laryngectomy for the treatment of T1N0M0 glottic carcinomas: a retrospective evaluation. *Radiother Oncol*. 1998;48(2):175-183.
- Van Gogh CD, Verdonck-de Leeuw IM, Wedler-Peeters J, Langendijk JA, Mahieu HF. Prospective evaluation of voice outcome during the first two years in male patients treated by radiotherapy or laser surgery for T1a glottic carcinoma. *Eur Arch Otorhinolaryngol*. 2012;269(6):1647-1652.
- Chu PY, Hsu YB, Lee TL, Fu S, Wang LM, Kao YC. Longitudinal analysis of voice quality in patients with early glottic cancer after transoral laser microsurgery. *Head Neck*. 2012;34(9):1294-1298.
- Lester SE, Rigby MH, McLean M, Taylor SM. 'How does that sound?': objective and subjective voice outcomes following CO(2) laser resection for early glottic cancer. *J Laryngol Otol*. 2011;125(12):1251-1255.
- Jotic A, Stankovic P, Jesic S, Milovanovic J, Stojanovic M, Djukic V. Voice quality after treatment of early glottic carcinoma. *J Voice*. 2012; 26(3):381-389.
- Keilmann A, Napiontek U, Engel C, Nakarat T, Schneider A, Mann W. Long-term functional outcome after unilateral cordectomy. *ORL J Otorhinolaryngol Relat Spec*. 2011;73(1):38-46.
- Xu W, Han D, Hou L, Zhang L, Yu Z, Huang Z. Voice function following CO2 laser microsurgery for precancerous and early-stage glottic carcinoma. *Acta Otolaryngol*. 2007; 127(6):637-641.
- Greene FL, Page DL, Fleming ID, et al. (eds). Part II head and neck sites. In: *AJCC Cancer Staging Handbook*. 6th ed. New York, NY: Springer; 2002:17-87.
- Remacle M, Eckel HE, Antonelli A, et al. Endoscopic cordectomy. A proposal for a classification by the Working Committee, European Laryngological Society. *Eur Arch Otorhinolaryngol*. 2000;257(4):227-231.
- Remacle M, Van Hauerbeke C, Eckel H, et al. Proposal for revision of the European Laryngological Society classification of endoscopic cordectomies. *Eur Arch Otorhinolaryngol*. 2007; 264(5):499-504.
- Lechien JR, Saussez S, Nacci A, et al. Association between laryngopharyngeal reflux and benign vocal folds lesions: a systematic review. *Laryngoscope*. 2019;129(9):E329-E341. doi:10.1002/lary.27932.
- Woisard V, Bodin S, Puech M. The Voice Handicap Index: impact of the translation in French on the validation [in French]. *Rev Laryngol Otol Rhinol (Bord)*. 2004;125(5):307-312.
- Hirano M. *Clinical Examination of Voice*. New York, NY: Springer-Verlag; 1981.
- Cohen SM, Garrett CG, Dupont WD, Ossoff RH, Courey MS. Voice-related quality of life in T1 glottic cancer: irradiation versus endoscopic excision. *Ann Otol Rhinol Laryngol*. 2006;115(8):581-586.
- Rosen CA, Murry T, Zinn A, Zullo T, Sonbolian M. Voice handicap index change following treatment of voice disorders. *J Voice*. 2000;14(4):619-623.
- Steen IN, MacKenzie K, Carding PN, Webb A, Deary IJ, Wilson JA. Optimising outcome assessment of voice interventions, II: sensitivity to change of self-reported and observer-rated measures. *J Laryngol Otol*. 2008;122(1):46-51.
- Cheng J, Woo P. Correlation between the voice handicap index and voice laboratory measurements after phonosurgery. *Ear Nose Throat J*. 2010;89(4):183-188.
- Galletti B, Freni F, Cammaroto G, Catalano N, Gangemi G, Galletti F. Vocal outcome after CO2 laser cordectomy performed on patients affected by early glottic carcinoma. *J Voice*. 2012; 26(6):801-805. doi:10.1016/j.jvoice.2012.01.003.

26. Lechien JR, Huet K, Finck C, et al. Are the acoustic measurements reliable in the assessment of voice quality? A methodological prospective study. *J Voice*. 2019;pii:S0892-1997(19)30328-5. doi:10.1016/j.jvoice.2019.08.022.
27. Lechien JR, Delvaux V, Huet K, et al. Phonetic approaches of laryngopharyngeal reflux disease: a prospective study. *J Voice*. 2017;31(1):119.e11-119.e20. doi:10.1016/j.jvoice.2016.02.020.
28. Hirano M. Morphological structure of the vocal cord as a vibrator and its variations. *Folia Phoniatr (Basel)*. 1974;26(2):89-94.
29. Roh JL, Kim DH, Kim SY, Park CI. Quality of life and voice in patients after laser cordectomy for Tis and T1 glottic carcinomas. *Head Neck*. 2007;29(11):1010-1016.
30. Dejonckere PH, Bradley P, Clemente P, et al. A basic protocol for functional assessment of voice pathology, especially for investigating the efficacy of (phonosurgical) treatments and evaluating new assessment techniques. Guideline elaborated by the Committee on Phoniatics of the European Laryngological Society (ELS). *Eur Arch Otorhinolaryngol*. 2001;258(2):77-82.
31. Lechien JR, Huet K, Finck C, et al. Clinical and acoustical voice quality evolutions throughout empirical treatment for laryngopharyngeal reflux disease according to gender: a preliminary study. *Folia Phoniatr Logop*. 2019:1-10. doi:10.1159/000500085.
32. Casimir GJ, Mulier S, Hanssens L, Zylberberg K, Duchateau J. Gender differences in inflammatory markers in children. *Shock*. 2010;33(3):258-262. doi:10.1097/SHK.0b013e3181b2b36b.