

Voice evaluation following endoscopic laser CO₂ cordectomy and conventional cordectomy

Magdalena Lachowska, Ewa Osuch-Wójcikiewicz, Antoni Bruzgielewicz

Department of Otolaryngology, Medical University of Warsaw, Poland

Submitted: 4 October 2009

Accepted: 28 October 2009

Arch Med Sci 2011; 7, 1: 143-153

DOI: 10.5114/aoms.2011.20621

Copyright © 2010 Termedia & Banach

Corresponding author:

Magdalena Lachowska MD, PhD

Department of Otolaryngology

Medical University

of Warsaw

Banacha 1a

02-097 Warsaw, Poland

Phone: +48 22 599 25 21

Fax: +48 22 599 25 23

E-mail: magdalena.lachowska@

wum.edu.pl

Abstract

Introduction: An analysis of long term voice quality outcomes of two different types of surgical intervention for Tis and T1 glottic carcinoma: laryngofissure conventional cordectomy and endoscopic laser CO₂ cordectomy, with or without additional radiation therapy.

Material and methods: Total of 46 patients with Tis and T1 glottic carcinoma served as subjects. All have been treated surgically with laryngofissure conventional cordectomy (32.61%) or endoscopic laser CO₂ cordectomy (67.39%). The surgeries were performed in the Department of Otolaryngology at the Medical University of Warsaw (1990-2004). The presented voice assessments were made at least 3 years following the surgery, in between January 2006 and February 2007.

Results: In patients after the endoscopic laser CO₂ cordectomy the following findings are more often observed: the unrestrained voice production, wider range of Fo in a spoken sentence, longer maximum phonation time, better intensity of phonation for normal and loud speaking, lower degree of hoarseness based on the Yanagihara's classification, and the lower VHI. No significant influence of the performed additional radiotherapy on voice parameters was found.

Conclusions: Patients after endoscopic laser CO₂ cordectomy, compared to laryngofissure conventional cordectomy, present better voice quality. The amount of the excised vocal fold tissue, which in our study was slightly larger in case of the conventional cordectomy, could account for the results mentioned above. This may also be explained by the necessity of the anterior thyrotomy, which is required for conventional cordectomy via external approach, and often results in anterior synechia and level difference between the neocord and the contralateral vocal fold.

Key words: glottic carcinoma, voice quality, spectrography, acoustic analysis of voice.

Introduction

A surgical intervention on the vocal folds may lead to their structural changes mainly due to damaged mucous membrane, whose thickness, mass, stiffness and elasticity play the main role in voice production. Post-surgical changes of the vocal folds' structure may lead to dysphonia [1]. The term dysphonia is used to define multiform voice disorders, affecting all acoustic components such as frequency, intensity, timbre and phonation time, exclusively or in groups. Hoarseness may be one of the elements of dysphonia [2, 3].

Endoscopic laser cordectomy and laryngofissure conventional cordectomy are surgical methods applied to the treatment for Tis and T1N0M0 glottic carcinoma. The goal of those two types of surgery is to achieve the best possible functional outcome including voice quality, while not compromising oncological principles. The oncological goal is always the most important in the case of cancer [4-7].

In 1982 in the Department of Otolaryngology at the Medical University of Warsaw, for the first time in Polish clinical practice, the CO₂ laser was used as a surgical knife in treatment for benign and malignant lesions of the larynx. Since then surgical methods of treatment using the CO₂ laser have continued to be developed and improved [8-10]. While performing the operation on the vocal folds, surgeons of our department always paid attention to the functional outcomes; this also concerns the quality of voice. Unfortunately, until now a summary of the long-term results of our work concerning voice quality after cordectomy has not been made or published. Performing all the research and statistics presented in this article gave us the possibility to critically sum up the outcomes of surgical treatment methods applied for Tis and T1N0M0 glottic carcinoma.

This paper is an analysis of long-term voice quality outcomes of two different types of surgical intervention for Tis and T1 glottic carcinoma: laryngofissure conventional cordectomy and endoscopic laser CO₂ cordectomy, with or without additional radiation therapy (using ⁶⁰Co).

Material and methods

A total of 46 patients with Tis and T1 glottic carcinoma, 43 men (93.48%) and 3 women (6.52%), served as subjects. All have been treated surgically with laryngofissure conventional cordectomy (15 patients, 32.61%) or endoscopic laser CO₂ cordectomy (31 patients, 67.39%). The operations were performed over a 14-year period in the Department of Otolaryngology at the Medical University of Warsaw, between November 1990 and February 2004.

The presented voice assessments were performed at least 3 years following the surgery, between January 2006 and February 2007. It is a retrospective study. The voice evaluation was conducted to analyse long-term functional results of the two different types of surgical interventions for Tis and T1 glottic carcinoma mentioned above.

The patients' age at the time of the primary surgery ranged from 35 to 79 with an average age of 61.02 (SD 9.54, median 59). The average age was similar in both compared groups.

Nowadays the indications for conventional cordectomy are limited. In our department this kind of surgery was performed in cases when laser CO₂

was inaccessible due to equipment failure. The study presents the voice quality outcomes following the operations that were made in the past; this fact limits the possibility of randomization. However, the coordination of the patients with the two groups (laser cordectomy or conventional cordectomy) depended on access to the laser. That made the patient allocation to the two groups in a way random and gave us the possibility to compare the functional results of those two different surgical methods.

The endoscopic laser excision of the vocal fold was comparable to the classification of endoscopic cordectomies presented by the European Laryngological Society (ELS) in 2000 [11]. Three types of endoscopic laser CO₂ cordectomy were performed:

1. Removal of the mucosa, the intermediate and deep layers of the lamina propria including the very superficial fibres of the adjacent vocal muscle – subligamental cordectomy or type II according to the ELS classification;
2. Removal of the medial portion of the vocal muscle – transmuscular cordectomy or type III according to the ELS classification;
3. Extended cordectomy involving the entire vocal fold and the anterior commissure extended to the contralateral vocal fold – type Va according to the ELS classification.

In the present study, two types of laryngofissure conventional cordectomy can be distinguished according to the amount of the excised tissue:

1. Removal of the vocal fold with part of or the entire anterior commissure;
2. Removal of the vocal fold with part of or the entire anterior commissure and vocal process of the arytenoid cartilage.

Comparison of the amount of resected tissue shows slightly larger resection through conventional cordectomy than laser cordectomy.

The voice evaluation was focused on the manner of voice production, phonation time, fundamental frequency, range of the fundamental frequency in a spoken sentence, analysis of hoarseness based on Yanagihara's classification, intensity of phonation, and the Voice Handicap Index (VHI).

The patients were divided into homogenous groups according to the treatment method – surgery alone or surgery with additional radiotherapy. The number of patients in groups was sufficient to perform the statistical analysis. Moreover, it allowed for evaluation of the influence of the additional radiological treatment on the functional results in patients after cordectomy.

The linguistics used in the presented study are the ones used in everyday work in the Phoniatic Outpatient Department, which is a part of the Diagnostic, Treatment and Rehabilitation Centre of Hearing and Voice Disorders of the Department of

Otolaryngology at the Medical University of Warsaw. The linguistics consists of the vowel set, single spoken words, simple sentences and read texts.

The Voice Handicap Index (VHI) introduced by Jacobson, in the modification made by Pruszewicz *et al.* [12], was also used. The VHI consists of 3 groups of questions, each having 10 elements.

The acoustic analysis was conducted using Computerized Speech Lab (CSL) with a 4150 External Module of KAY Elemetrics Corporation. The recordings of voice for the acoustic analysis were carried out in a quiet room with a microphone placed 15 cm from the patient's mouth. The intensity of voice was measured with the microphone at a distance of 30 cm from the mouth.

Statistical analysis

A versatile statistical analysis using appropriate methods was carried out. StatSoft Inc. 2005 Statistica software version 7.1 (data analysis software system), and literature on statistics in medicine were used [13]. Appropriate methods were selected for the proper statistical analysis. *P*-values of < 0.05 were considered significant. Basic and detailed statistics were performed. The normality of the distribution for quantitative variables was verified. The Student-*t* test, variation tests and detailed tests were used. The analysis of correlation, independence test, chi-square test, and Fisher's test were also used.

Results

Patient grouping scheme according to surgical methods and additional radiotherapy

The patients (*n* = 46) were divided into groups A, B, C, D and E according to the treatment method – surgery alone (laser or conventional cordectomy) or surgery with additional radiotherapy. The number of patients in groups A, B, D, E was sufficient to perform the statistical analysis. Group C was excluded from the analysis due to the small number of patients in that group (1 patient) in order to obtain reliable statistical results. Group C was included in the tables for a full picture (Table I).

Manner of voice production

The manner of voice production was evaluated according to the observation and palpation of the patients' neck while speaking in free conversation. Most of the patients presented strained voice production with visible hyperfunction of the laryngeal and neck muscles. Almost all patients with unrestrained voice production belonged to the laser cordectomy groups (A and B). The results are presented in Table II.

Phonation time

A shorter phonation time was observed in patients after conventional cordectomy; in group D the average was 8.30 s and in group E 11.00 s (SD 3.80 and 8.34 respectively). In patients after endoscopic laser CO₂ cordectomy it was 13.68s in group A and 14.27s in group B (SD 4.07 and 5.92 respectively). The average maximum phonation time in all groups together was 12.50s, and ranged from 3 to 27 (SD 5.50).

Fundamental frequency

To establish whether the fundamental frequency is within normal limits, the gender of the patients must be taken into account. In our study only 3 females underwent cordectomy, and for that reason they were not included in the statistical analysis (insufficient number for reliable analysis). The presented results are valid for male patients.

Table I. Patients grouping scheme according to the treatment method – the surgery alone (laser or conventional cordectomy) or the surgery with additional radiotherapy (*n* = 46)

Group	Treatment method	Number of patients
A	laser cordectomy	19
B	laser cordectomy + radiotherapy	11
C	laser cordectomy + radiotherapy + conventional cordectomy	1
D	conventional cordectomy or conventional cordectomy following laser surgery	10
E	conventional cordectomy + radiotherapy	5

Table II. Manner of voice production while speaking in free conversation, according to the method of the surgical treatment (conventional or laser cordectomy) with or without additional radiotherapy (*n* = 46)

Group	Voice production	
	Unrestrained (number of patients)	Strained with visible hyperfunction of the laryngeal and neck muscles (number of patients)
A	9	10
B	4	7
C	-	1
D	1	9
E	-	5
ABCDE	14	32
% of <i>n</i>	30.43%	69.57%

The average fundamental frequency in the groups after laser cordectomy (groups A and B) was 150.29 Hz and 152.50 Hz respectively (SD 23.23 and 35.85 respectively) (for groups A and B together the mean Fo was 151.11 Hz). In groups after conventional cordectomy (groups D and E) it was 124.40 Hz and 119.80 Hz respectively (SD 33.56 and 33.85 respectively) (for groups D and E together the mean Fo was 122.87 Hz). There were 2 patients after conventional cordectomy who presented phonation at the level of the vestibular folds (1 patient in group D and 1 in group E) with the fundamental frequency at 58 Hz and 70 Hz.

Range of the fundamental frequency in a spoken sentence using semitones

The range of Fo in a spoken sentence was evaluated using spectrographs of the Polish sentence “Ten dzielny żołnierz był z nim razem” (The brave soldier stayed together with him) (Figures 1 and 2). It was impossible to establish the range of the fundamental frequency in 3 patients due to a lot of noise components in the spectrographs (1 patient in group B and 2 in group E).

The average range of Fo in patients after laser cordectomy (groups A and B) was 13.37 semitones and 11.50 semitones respectively (SD 2.54 and 2.55 respectively). In patients after conventional cordectomy (group D and E) it was 10.80 semitones and 11.67 semitones respectively (SD 3.19 and 1.15 respectively).

Analysis of hoarseness based on Yanagihara’s classification

The spectrographic analysis of the vowels /i/ /e/ /a/ was used for evaluation of the degree of hoarseness. The analysis revealed that the patients after endoscopic laser cordectomy (groups A and B) presented less hoarse voice than the patients after laryngofissure conventional cordectomy (groups D and E). The results are presented in Table III, and examples in Figures 3, 4, 5, 6 and 7.

Intensity of phonation – normal speaking and loud speaking

The intensity of phonation, both in normal speaking and loud speaking measured at a distance of 30 cm from the patient’s mouth, was higher

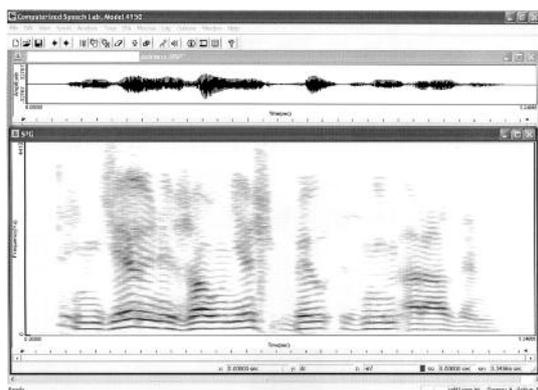


Figure 1. Narrowband spectrograph of the sentence “Ten dzielny żołnierz był z nim razem” (The brave soldier stayed together with him) in a patient after endoscopic laser CO₂ cordectomy of the right vocal fold

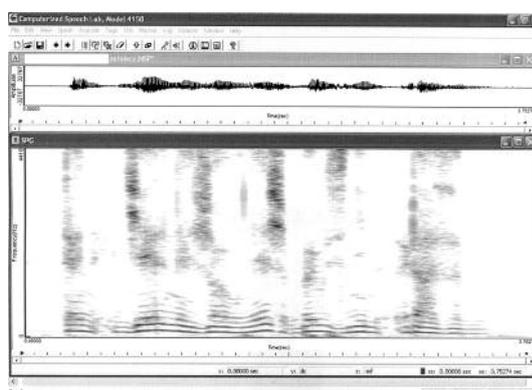


Figure 2. Narrowband spectrograph of the sentence “Ten dzielny żołnierz był z nim razem” (The brave soldier stayed together with him) in a patient after conventional cordectomy of the left vocal fold

Table III. Degree of hoarseness based on the Yanagihara’s classification according to the method of the surgical treatment (conventional or laser cordectomy) with or without additional radiotherapy (n = 46)

Group	Degree of hoarseness based on the Yanagihara’s classification			
	I (number of patients)	II (number of patients)	III (number of patients)	IV (number of patients)
A	1	10	7	1
B	–	7	1	3
C	–	–	–	1
D	–	–	4	6
E	–	–	4	1
ABCDE	1	17	16	12
% of n	2.17%	36.96%	34.78%	26.09%

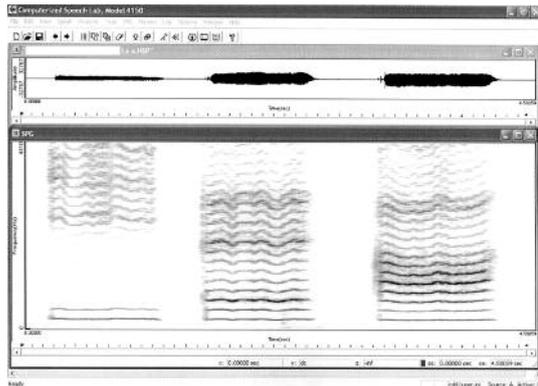


Figure 3. Narrowband spectrograph of the vowels /i/ /e/ /a/ in a patient after endoscopic laser CO₂ cordectomy of the right vocal fold – grade I hoarseness

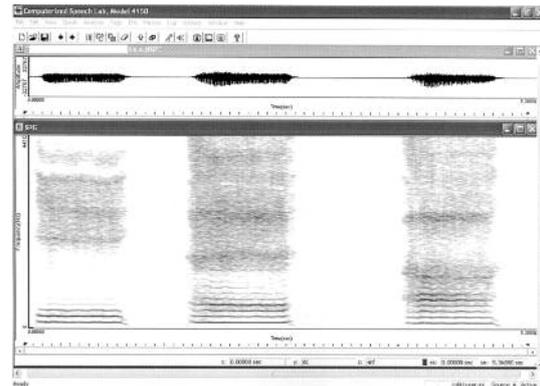


Figure 5. Narrowband spectrograph of the vowels /i/ /e/ /a/ in a patient after endoscopic laser CO₂ cordectomy of the left vocal fold – grade III hoarseness

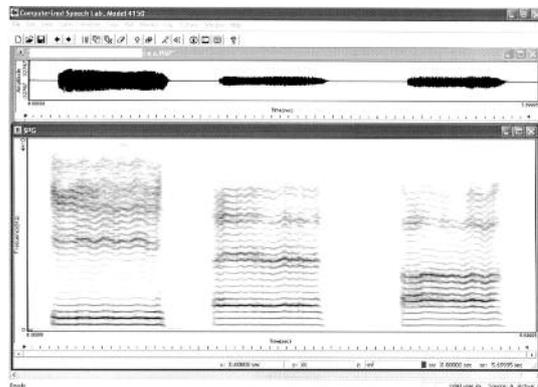


Figure 4. Narrowband spectrograph of the vowels /i/ /e/ /a/ in a patient after endoscopic laser CO₂ cordectomy of the right vocal fold – grade II hoarseness

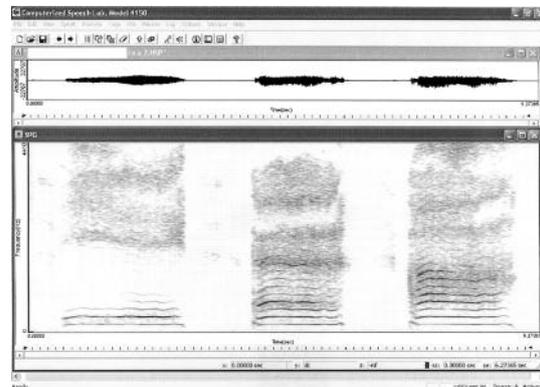


Figure 6. Narrowband spectrograph of the vowels /i/ /e/ /a/ in a patient after conventional cordectomy of the right vocal fold – grade III hoarseness

in patients after endoscopic laser cordectomy (groups A and B) compared to the patients after conventional cordectomy (groups D and E). The mean values are presented in Table IV.

Voice Handicap Index

The VHI scores indicate that all groups had subjective voice problems, but the CO₂ laser cordectomy groups (A and B) presented lower values and the conventional cordectomy groups (D and E) higher values. The mean values of VHI are presented in Table V.

Analysis of correlation

The analysis of correlation was performed for the fundamental frequency values, range of Fo in semitones, phonation time, intensity of phonation in dB for normal and loud speaking, and the VHI. Significant *p*-values for correlation (*p* < 0.05) were found for:

- phonation time and VHI (*p* = 0.022),

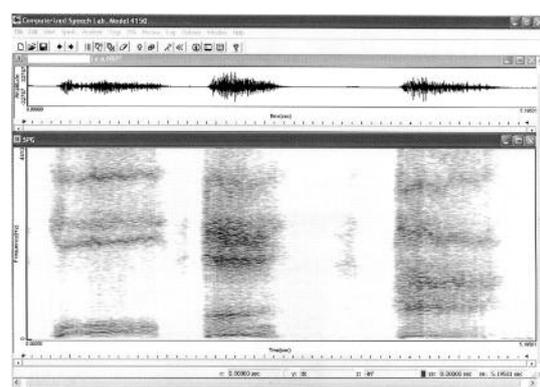


Figure 7. Narrowband spectrograph of the vowels /i/ /e/ /a/ in a patient after conventional cordectomy of the left vocal fold – grade IV hoarseness

- intensity of phonation in normal and loud speaking (*p* = 0.000),
- VHI and intensity of phonation in loud speaking (*p* = 0.000).

Table IV. Mean values of phonation intensity in normal and loud speaking according to the method of the surgical treatment (conventional or laser cordectomy) with or without additional radiotherapy ($n = 46$)

Group	Mean intensity [dB]		SD	
	Normal speaking	Loud speaking	Normal speaking	Loud speaking
A	66.37	81.00	2.69	3.02
B	67.09	81.91	2.39	3.42
C	64	76	–	–
D	64.40	77.30	1.96	3.02
E	64.80	77.20	3.27	4.32
ABCDE	65.89	79.89	2.65	3.73

Table V. Voice Handicap Index (VHI) according to the method of the surgical treatment (conventional or laser cordectomy) with or without additional radiotherapy ($n = 46$)

Group	VHI						Mean points VHI	SD
	0-30 pts		31-60 pts		61-120 pts			
	Number of patients	Mean points	Number of patients	Mean points	Number of patients	Mean points		
A	10	12.1	9	42.4	–	–	26.47	17.59
B	9	14.1	2	40	–	–	18.82	12.07
C	1	22	–	–	–	–	22	–
D	4	19.5	4	47.8	2	66	40.10	20.05
E	–	–	4	47	1	73	52.20	14.48
ABCDE	24	14.5	19	44.3	3	68.3	30.30	19.23

Variation tests for evaluation of the influence of cordectomy type and subsequent radiotherapy on the acoustic analysis results

Comparison of laser cordectomy vs. conventional cordectomy

The evaluation of the influence of cordectomy type (laser vs. conventional; group A vs. D) on voice parameters such as the fundamental frequency values, range of Fo in semitones, phonation time, intensity of phonation in dB for normal and loud speaking, and the VHI was carried out.

The analysis revealed significant p-values for the range of Fo in semitones ($p = 0.0253$), phonation time ($p = 0.0018$), and intensity of phonation in loud speaking ($p = 0.0041$), which presented better results in patients after laser cordectomy. However, the fundamental frequency was significantly better in patients after conventional cordectomy ($p = 0.0257$) (Table VI).

Comparison of laser cordectomy with radiotherapy vs. conventional cordectomy with radiotherapy

The evaluation of the influence of cordectomy type followed by additional radiotherapy (group B

vs. E) on voice parameters such as the fundamental frequency values, range of Fo in semitones, phonation time, intensity of phonation in dB for normal and loud speaking, and VHI was carried out.

The analysis revealed significant p-values for the intensity of phonation in loud speaking ($p = 0.0334$), and the VHI ($p = 0.0003$), which presented better results in patients after laser cordectomy (Table VII).

Comparison of laser cordectomy and laser cordectomy with radiotherapy vs. conventional cordectomy and conventional cordectomy with radiotherapy

The evaluation of the influence of cordectomy type with or without additional radiotherapy (groups A and B vs. D and E) on voice parameters such as the fundamental frequency values, range of Fo in semitones, phonation time, intensity of phonation in dB for normal and loud speaking, and the VHI was carried out.

The analysis revealed significant p-values for the phonation time ($p = 0.0050$), intensity of phonation in normal speaking ($p = 0.0110$) and loud speaking ($p = 0.0002$), and the VHI ($p = 0.0004$), which presented better results in

Table VI. Evaluation of the cordectomy type (laser vs. conventional, the group A vs. D) influence on the acoustic analysis results

Parameter	Group A			Group D			P value of the F test	P value of the Student-t test
	Mean value	n	SD	Mean value	n	SD		
Fundamental frequency [Hz]	150.29	17	23.23	124.40	10	33.56	0.1908	0.0257*
Range of Fo [semitones]	13.37	19	2.54	10.80	10	3.19	0.3945	0.0253*
Phonation time [s]	13.68	19	4.07	8.30	10	3.80	0.8694	0.0018*
Intensity of phonation in normal speaking [dB]	66.37	19	2.69	64.40	10	1.96	0.3282	0.0513
Intensity of phonation in loud speaking [dB]	81.00	19	3.02	77.30	10	3.02	0.9467	0.0041*
VHI points	26.47	19	17.59	40.10	10	20.05	0.6069	0.0694

*p-values of < 0.05 are significant

Table VII. Evaluation of the cordectomy type followed by radiotherapy (laser cordectomy with radiotherapy vs. conventional cordectomy with radiotherapy, group B vs. E) influence on acoustic analysis results

Parameter	Group B			Group E			P value of the F test	P value of the Student-t test
	Mean value	n	SD	Mean value	n	SD		
Fundamental frequency [Hz]	152.50	10	35.85	119.80	5	33.85	0.9857	0.1141
Range of Fo [semitones]	11.50	10	2.55	11.67	3	1.15	0.3635	0.9164
Phonation time [s]	14.27	11	5.92	11.00	5	8.34	0.3459	0.3803
Intensity of phonation in normal speaking [db]	67.09	11	2.39	64.80	5	3.27	0.3811	0.1338
Intensity of phonation in loud speaking [dB]	81.91	11	3.42	77.20	5	4.32	0.4977	0.0334*
VHI points	18.82	11	12.07	52.20	5	14.48	0.5824	0.0003*

*p-values of < 0.05 are significant

patients after laser cordectomy. However, the fundamental frequency was significantly better in patients after conventional cordectomy ($p = 0.0051$) (Table VIII).

Variation analysis of two factors

The variation analysis of two factors evaluated whether the following factors have a significant influence on the voice parameters (the fundamental

frequency values, range of Fo in semitones, phonation time, intensity of phonation in dB for normal and loud speaking, and the VHI):

- factor 1 – the type of cordectomy (laser or conventional),
- factor 2 – additional radiotherapy (performed or not performed),
- interaction of factors 1 and 2 – interaction of the two analysed factors.

Table VIII. Evaluation of the cordectomy type with or without additional radiotherapy (group A and B vs. D and E) influence on acoustic analysis results

Parameter	Group A and B			Group D and E			P value of the F test	P value of the Student-t test
	Mean value	n	SD	Mean value	n	SD		
Fundamental frequency [hz]	151.11	27	27.90	122.87	15	32.50	0.4842	0.0051*
Range of Fo [semitones]	12.72	29	2.66	11.00	13	2.83	0.7496	0.0639
Phonation time [s]	13.90	30	4.74	9.20	15	5.56	0.4525	0.0050*
Intensity of phonation in normal speaking [db]	66.63	30	2.57	64.53	15	2.36	0.7578	0.0110*
Intensity of phonation in loud speaking [db]	81.33	30	3.14	77.27	15	3.35	0.7447	0.0002*
VHI points	23.67	30	16.01	44.13	15	18.79	0.4520	0.0004*

*p-values of < 0.05 are significant

The analysis revealed that the type of cordectomy had an influence on the following voice parameters (Table IX):

- fundamental frequency ($p = 0.0070$),
- phonation time ($p = 0.0142$),

- intensity of phonation in normal speaking ($p = 0.0158$),
- intensity of phonation in loud speaking ($p = 0.0004$),
- the VHI ($p = 0.0001$).

Table IX. Variation analysis of two factors

Voice parameter	Factor	F	P-value
Mean fundamental frequency	1	8.142	0.0070*
	2	0.014	0.9078
	12	0.110	0.7421
Range of Fo	1	1.390	0.2458
	2	0.242	0.6258
	12	1.802	0.1874
Phonation time	1	6.558	0.0142*
	2	0.946	0.3364
	12	0.390	0.5357
Intensity of phonation in normal speaking	1	6.340	0.0158*
	2	0.440	0.5107
	12	0.036	0.8498
Intensity of phonation in loud speaking	1	14.930	0.0004*
	2	0.138	0.7120
	12	0.215	0.6453
VHI	1	17.787	0.0001*
	2	0.159	0.6921
	12	3.141	0.0838

*p-values of < 0.05 are significant

There was no significant influence of the additional radiotherapy on the voice parameters ($p > 0.05$). There was no significant influence of the interaction of the two analysed factors on the voice parameters ($p > 0.05$) (Table IX).

The independence test and Wanke's excess

The statistical analysis revealed that the additional radiotherapy after the surgery did not significantly influence the functional outcomes ($p > 0.05$). This allowed us to classify patients into larger groups (group A with B together, and group D with E together) and perform the independence test. Wanke's excess was calculated to facilitate interpretation of the results of the independence test (Wanke's excess is considered valid when it is > 1 , which confirms the analysed feature as statistically significant).

The manner of voice production and hoarseness degree based on Yanagihara's classification were analysed using the mentioned tests.

The independence test showed statistically a considerably higher occurrence of the following parameters in the patients after endoscopic laser cordectomy ($p < 0.05$, Wanke's excess > 1):

- unrestrained voice production ($p = 0.0164$, Wanke's excess 1.39),

- lower degree of hoarseness based on Yanagihara's classification ($p = 0.0001$, Wanke's excess 1.50).

Discussion

After the removal of the vocal fold invaded by the glottic carcinoma a scar develops and takes over the function of the vocal fold. Kregli *et al.* evaluated voice outcomes at a minimum of 2 years after the laser cordectomy to be sure that the post-treatment changes were stabilized. The electroacoustic analysis of the voice detected type II – III hoarseness based on Yanagihara's classification in 30% of patients, while severe dysphonia (type IV of Yanagihara) was observed in 70%. The mean value of fundamental frequency was 134.5 Hz [14].

Different results to Kregli *et al.* were reported by McGuirt *et al.* In most patients after endoscopic laser cordectomy grade III hoarseness of Yanagihara was detected. The mean value of the voice intensity was 43 dB, and the maximum phonation time was 16.01 s. Patients themselves rated their voice as normal or close to normal [15].

In Remacle *et al.*'s opinion the debate concerning the results of vocal quality after radiotherapy or endoscopic laser cordectomy remains open. Some authors claim no differences in voice quality after either procedure while others maintain that the radiotherapy is better. It is difficult to compare treatment methods because of the differences among authors in the extent of the cordectomy, techniques of radiotherapy, ways of patient selection and the methods of voice evaluation. Remacle *et al.* are not in favour of radiotherapy for the treatment of T1 vocal fold carcinoma, even if there is any doubt with regard to the vocal quality after the surgery [16].

In the present study no significant influence of the additional radiotherapy, performed in some patients, on voice parameters was found. This allows us to conclude that when it comes to voice quality most important was the method of surgical treatment, and the influence of the complimentary radiation therapy was not significant.

Betlejewski *et al.* reported a long-term follow-up study of patients after laser cordectomy performed due to glottic carcinoma. The voice evaluation, conducted just after healing of the glottis, revealed the mean value of the maximum phonation time at 10 s. The mean fundamental frequency was quite high at 170 Hz in males and quite low at 178 Hz in females. The second voice examination was performed 3 years later and revealed an increase in maximum phonation time up to 11.8 s, lowering of the males' voices to 160 Hz, and increase of the fundamental frequency in females to the mean value of 190 Hz. Eight to ten years after the surgery

a further decrease of F_0 in males (mean value of 154 Hz), and increase of F_0 in females (mean value of 204 Hz) was observed. The maximum phonation time increased to 15.4 s. The voice characteristics changed from hoarse to pure. The authors concluded that the smooth and straight neocord in place of the excised vocal fold creates good conditions for voice emission [17]. In our study the mean value of the fundamental frequency was higher in the group of patients after laser surgery (151.11 Hz) compared to patients after conventional cordectomy (122.87), where the mean value was close to the normal F_0 (for males it is taken to be about 128 Hz).

In their study, Keilmann *et al.*, investigated and compared voice outcomes in patients after conventional cordectomy and after laser cordectomy. The study revealed that patients after laser surgery more often presented better voice quality in the spectrograph classification based on Yanagihara. As for the fundamental frequency and the maximum phonation time there were no statistical differences between the groups of patients [18].

Schindler *et al.* conducted a comparable study of voice evaluation following conventional cordectomy and laser cordectomy in patients operated on for early glottic cancer. They analysed the maximum phonation time, degree of hoarseness based on Yanagihara's classification, voice perturbation, and the GRBAS scale. The results were slightly better in patients after conventional cordectomy. However, the detailed analysis did not prove any statistical significance indicating the superiority of any of the presented surgical methods [19].

In our study in patients after endoscopic laser cordectomy the following findings were more often observed: unrestrained voice production and lower degree of hoarseness based on Yanagihara's classification. Moreover the statistical analysis proved that the following voice parameters depend on the surgical treatment method: the range of F_0 in a spoken sentence, maximum phonation time, intensity of phonation for normal and loud speaking, and the VHI. The above-mentioned parameters were found to be better in patients after laser cordectomy.

Remacle *et al.* reported that the voice quality depended on the extent of resection of the vocal fold in patients undergoing laser cordectomy. The spectrographic examination revealed better results in patients with smaller tissue resection of the vocal fold. The values for the maximum phonation time and vocal intensity did not differ significantly among patients [16]. Modrzejewski *et al.* analysed acoustically patients after conventional cordectomy and did not find any significant differences in the fundamental frequency according to the amount of excised tissue of the vocal fold [20].

The connection between voice quality and the depth of the excision of the vocal fold was proved by Delsupehe *et al.*, who evaluated the perceptual voice characteristics in patients after laser cordectomy. The authors also noted that there was clear improvement for most of the voice characteristics over time [21]. As Mendenhall *et al.* reported, in their literature review, most of the studies presented in international articles did not investigate large groups of patients. However, analysis of them revealed that voice quality becomes poorer with laser resections of larger tumours [5].

Like many other authors, Peretti *et al.* also considered that vocal outcomes are strictly related to glottic competence, which depends on the amount of resected vocal fold tissue. In their opinion, the preservation of the anterior commissure and most of the vocal muscle plays a key role in obtaining good and close to normal voice quality [22]. Sittel *et al.* reported that for the vocal result the preservation of the anterior commissure is most important, in contrast to no linear correlation between the amount of the removed glottic tissue and postoperative voice results. In their opinion, the most important factor is the mechanism of the postoperative phonation after laser cordectomy [23]. In our study the reason for the obtained results could be the amount of the excised vocal fold tissue, which was slightly larger in the case of conventional cordectomy. This can also be explained by the formation of the anterior synechia and the level difference between the neocord and the contralateral vocal fold in the patients after conventional cordectomy via the external route, which requires an anterior thyrotomy. Bertino *et al.* believed that the postoperative voice quality depends on the shape of the neocord and the phonatory mechanism adopted by the patient after the cordectomy [24].

To conclude, our study revealed that in patients after endoscopic laser CO₂ cordectomy, compared to laryngofissure conventional cordectomy, the following findings are more often observed: unrestrained voice production, wider range of Fo in a spoken sentence, longer maximum phonation time, better intensity of phonation for normal and loud speaking, lower degree of hoarseness based on Yanagihara's classification, and lower VHI. The amount of excised vocal fold tissue, which in our study was slightly larger in the case of conventional cordectomy, could account for the results mentioned above. This may also be explained by the necessity of anterior thyrotomy, which is required in conventional cordectomy via an external approach, and often results in anterior synechia and a level difference between the neocord and the contralateral vocal fold. No significant influence of additional radiotherapy on voice parameters was found.

References

1. Krzeski A, Maniecka-Aleksndrowicz B, Lachowska M. Podstawy chirurgicznego leczenia dysfonii [Polish]. *Magazyn Otorinolaryngologiczny* 2005; 15: 91-8.
2. Maniecka-Aleksndrowicz B, Domeracka-Kołodziej A. Dysfonia i chrypka [Polish]. *Magazyn Otorinolaryngologiczny* 2004; 9: 17-25.
3. Wiskirska-Woźnica B. Kompleksowa ocena głosu w schorzeniach organicznych i czynnościowych krtani. *Rozprawa habilitacyjna* [Polish]. Akademia Medyczna, Poznań 2002.
4. McWhorter AJ, Hoffman HT. Transoral laser microsurgery for laryngeal malignancies. *Curr Probl Cancer* 2005; 29: 180-9.
5. Mendenhall WM, Werning JW, Hinerman RW, Amdur RJ, Villaret DB. Management of T1-T2 glottic carcinomas. *Cancer* 2004; 100: 1786-92.
6. Peretti G, Nicolai P, Redaelli de Zinis LO, et al. Endoscopic CO₂ laser excision for Tis, T1, and T2 glottic carcinomas: cure rate and prognostic factors. *Otolaryngol Head Neck Surg* 2000; 123: 124-31.
7. Pukander J, Kerälä J, Mäkitie A, Hyrynkangas K, Virtaniemi J, Grenman R. Endoscopic laser surgery for laryngeal cancer. *Eur Arch Otorhinolaryngol* 2001; 258: 236-9.
8. Janczewski G, Sonnenberg Z, Połubiński R. Laser jako narzędzie chirurgiczne [Polish]. *Otolaryngol Pol* 1982; 36: 181-6.
9. Połubiński R. Ocena kliniczna wartości lasera CO₂ stosowanego w mikrochirurgii wybranych schorzeń nienowotworowych krtani. *Praca doktorska* [Polish]. Warszawa 1985.
10. Sonnenberg Z. Laser CO₂ w leczeniu stanów przedrakowych krtani. *Praca habilitacyjna* [Polish]. Warszawa 1987.
11. Remacle M, Eckel HE, Antonelli A, et al. Endoscopic cordectomy. A proposal for classification by the Working Committee, European Laryngological Society. *Eur Arch Otorhinolaryngol* 2000; 257: 227-31.
12. Pruszewicz A, Obrębowski A, Wiskirska-Woźnica B, Wojnowski W. W sprawie kompleksowej oceny głosu – własna modyfikacja testu samooceny niesprawności głosu (Voice Handicap Index) [Polish]. *Otolaryngol Pol* 2004; 58: 547-9.
13. Petrie A, Sabin C. *Statystyka medyczna w zarysie* [Polish]. Wydawnictwo Lekarskie PZWL 2006.
14. Krenkli M, Policarpo M, Manfreda I, et al. Voice quality after treatment for T1a glottic carcinoma – radiotherapy versus laser cordectomy. *Acta Oncol* 2004; 43: 284-9.
15. McGuirt WF, Blalock D, Koufman JA, Feehs RS. Voice analysis of patients with endoscopically treated early laryngeal carcinoma. *Ann Otol Rhinol Laryngol* 1992; 101: 142-46.
16. Remacle M, Lawson G, Jamart J, Minet M, Watelet JB, Delos M. CO₂ laser in the diagnosis and treatment of early cancer of the vocal fold. *Eur Arch Otorhinolaryngol* 1997; 254: 169-76.
17. Betlejewski S, Sinkiewicz A, Mackiewicz-Nartowicz H. Odległe wyniki leczenia raka krtani T1 i T2 w mikrochirurgii laserowej [Polish]. *Otolaryngol Pol* 2005; 59: 235-7.
18. Keilmann A, Bergler W, Artzt M, Hörmann K. Vocal function following laser and conventional surgery of small malignant vocal fold tumours. *J Laryngol Otol* 1996; 110: 1138-41.
19. Schindler A, Palonta F, Preti G, Ottaviani F, Schindler O, Cavalot AL. Voice quality after carbon dioxide laser and conventional surgery for T1a glottic carcinoma. *J Voice* 2004; 18: 545-50.

20. Modrzejewski M, Olszewski E, Wszotek W, Reroń E, Stręk P. Acoustic assessment of voice signal deformation after partial surgery of the larynx. *Auris Nasus Larynx* 1999; 26: 183-90
21. Delsupehe KG, Zink I, Lejaegere M, Bastian RW. Voice quality after narrow-margin laser cordectomy compared with laryngeal irradiation. *Otolaryngol Head Neck Surg* 1999; 121: 528-33.
22. Peretti G, Piazza C, Balzanelli C, Cantarella G, Nicolai P. Vocal outcome after endoscopic cordectomies for Tis and T1 glottic carcinomas. *Ann Otol Rhinol Laryngol* 2003; 112: 174-9.
23. Sittel C, Eckel HE, Eschenburg C. Phonatory results after laser surgery for glottic carcinoma. *Otolaryngol Head Neck Surg* 1998; 119: 418-24.
24. Bertino G, Bellomo A, Ferrero FE, Ferlito A. Acoustic Analysis of voice quality with or without false vocal fold displacement after cordectomy. *J Voice* 2001; 15: 131-40.