Videolaryngoscopic and videostroboscopic evaluation following laser CO_2 and conventional cordectomy of T_{is} and T_1 glottic carcinoma

Magdalena Lachowska, Ewa Osuch-Wójcikiewicz, Antoni Bruzgielewicz

Department of Otolaryngology, Medical University of Warsaw, Poland

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Corresponding author:
Magdalena Lachowska, MD, PhD
Department of Otolaryngology
Medical University of Warsaw
1a Banacha Str.
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: This paper is an analysis of long-term functional results, observed on videolaryngoscopic and videostroboscopic examination, of two different types of surgical intervention for T_{is} and T_1 glottic carcinoma: laryngofissure conventional cordectomy and endoscopic laser CO_2 cordectomy, with or without additional radiation therapy (using ^{60}Co).

Material and methods: A total of 46 patients with T_{is} and T_1 glottic carcinoma, 43 men (93.48%) and 3 women (6.52%), served as subjects. All were treated surgically with laryngofissure conventional cordectomy (15 patients, 32.61%) or endoscopic laser CO_2 cordectomy (31 patients, 67.39%). The procedures were performed in the Department of Otolaryngology at the Medical University of Warsaw between November 1990 and February 2004. Videolaryngoscopic and videostroboscopic examinations were conducted a minimum of 3 years after the surgery, between January 2006 and February 2007. The appearance of the neocord (the scar after cordectomy), scar or synechia formation in the anterior commissure, movements of the vocal folds on respiration and phonation, difference in level between the neocord and the normal vocal fold, glottic closure, phonation type, and ventricular folds hyperfunction were examined. The symmetry of vocal fold vibrations, regularity of vibrations, glottic closure, amplitude of vibrations, and mucosal wave were also evaluated.

Results: In our study, the videolaryngoscopic and videolaryngostroboscopic examination showed a significantly higher occurrence of the following findings in patients after endoscopic laser cordectomy: phonation at the glottic level, complete glottic closure, and a tendency to vibration of the neocord on phonation.

Conclusions: Ventricular hyperfunction on phonation and scar or synechia formation in the anterior commissure were observed statistically more frequently in patients after laryngofissure conventional cordectomy.

Key words: glottic closure, ventricular hyperfunction, anterior commissure, vocal fold vibrations, mucosal wave.

Introduction

The vocal folds play a fundamental role in the phonatory function of the larynx. Each surgical intervention on the vocal fold may lead to an irreversible abnormal vibratory pattern on phonation due to damaged vocal fold mucosa, whose thickness, mass, stiffness and elasticity play the main role in voice production. Structural changes of the vocal fold, including postoperative scarring, lead to an abnormal vibration, and have a negative influence on the voice quality [1].

Endoscopic laser cordectomy and laryngofissure conventional cordectomy are surgical methods applied for the treatment of Tis and T1N0M0 glottic carcinoma. The oncological goal is always the most important in case of a cancer. However, the technical innovations for surgery, precision of tumour removal and surgical experience offer the possibility to take into account the best possible functional outcome, including voice quality, while not compromising oncological principles [2].

In 1982 in the Department of Otolaryngology at the Medical University of Warsaw, for the first time in Polish clinical practice, the CO_2 laser was used as a surgical knife in the treatment of benign and malignant lesions of the larynx. Since then surgical methods of treatment using CO_2 laser have been developed and improved [3-5]. The present study is the first in our Department that sums up the long-term results of our work concerning functional outcomes after cordectomy. Performing all the research and statistics presented in this article gave us the possibility to critically sum up surgical treatment methods applied for T_{is} and T1N0M0 glottic carcinoma.

This paper is an analysis of long-term functional results, observed on videolaryngoscopic and videostroboscopic examination, of two different types of surgical intervention for T_{is} and T_1 glottic carcinoma: laryngofissure conventional cordectomy and endoscopic laser CO_2 cordectomy, with or without additional radiation therapy (using ^{60}Co).

Material and methods

A total of 46 patients with T_{is} and T_1 glottic carcinoma, 43 men (93.48%) and 3 women (6.52%), served as subjects. All were treated surgically with laryngofissure conventional cordectomy (15 patients, 32.61%) or endoscopic laser CO_2 cordectomy (31 patients, 67.39%). The procedures were performed in the Department of Otolaryngology at the Medical University of Warsaw between November 1990 and February 2004.

Videolaryngoscopic and videostroboscopic examinations were conducted a minimum of 3 years after the surgery, between January 2006 and February 2007. It is a retrospective study. The videolaryngoscopic and videostroboscopic examinations were performed to analyse long-term functional results of the two different types of surgical intervention for T_{is} and T_1 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 CO_2 was inaccessible due to equipment failure. The study presents the functional outcomes following operations that were made in the past; this fact limits the possibility of randomization. However, assignment of the patients to the two groups (laser cordectomy or conventional cordectomy) depended on access to the laser. That made patient selection 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 [6]. Three types of endoscopic laser CO_2 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 excised tissue:

1) removal of the vocal fold with part or the entire anterior commissure;
2) removal of the vocal fold with part 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 patients were divided into homogeneous groups according to the treatment method – surgery alone or surgery with additional radiotherapy. The number of patients in the 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 videolaryngostroboscopy was conducted using the STORZ 8020 Stroboscope coupled with a 90-degree rigid laryngoscope. The video and stroboscopic images were analysed at normal speed, in slow mode and in stop mode. The appearance of the neocord (the scar after cordectomy), scar or synechia formation in the anterior commissure, movements of the vocal folds on respiration and phonation, difference in level between the neocord and the normal vocal fold, glottic closure, phonation type, and ventricular folds hyperfunction were examined. The Bless, Hirano

and Feder rating form was followed while performing the stroboscopy [7]. The symmetry of vocal fold vibrations, regularity of vibrations, glottic closure, amplitude of vibrations, and mucosal wave were evaluated.

Statistical analysis

A versatile statistical analysis using adequate methods was carried out. The StatSoft Inc. 2005 Statistica software version 7.1 (data analysis software system) and literature on statistics in medicine were used [8]. Adequate methods were selected for the proper statistical analysis. Values of $p < 0.05$ were considered significant. Basic and detailed statistics were performed. The normality of the distribution for quantitative variables was verified. Student's *t*-test, χ^2 test, independence 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 a reliable statistical analysis. Group C was included in tables for a full picture (Table I).

Table I. Patient grouping scheme according to treatment method – surgery alone (laser or conventional cordectomy) or 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

Videolaryngoscopy and videostroboscopy

Post-cordectomy neocord appearance

On the videolaryngoscopy and indirect mirror examination of the larynx, additional tissue formation on the neocord in 3 patients was noticed (1 patient in groups A, C and D). Microsurgery was performed. Histopathological examination revealed no cancer in the excised tissues. In the remaining 43 patients (93.48%) the neocord was smooth and straight (Figures 1, 2).

In group A the examination revealed a wide neocord in 5 patients, narrow in 1 patient, and in the remaining patients the width was similar to the contralateral vocal fold. In group B the neocord was wide in 1 patient, and in the remaining patients the width was similar to the contralateral vocal fold. One patient from group C presented the neocord slightly narrower than the opposite side. In group D the examination showed a narrow neocord in 2 patients; the remaining patients presented the neocord slightly narrower than the contralateral vocal fold. In group E the neocord was very narrow in 1 patient, wide in 1 patient; the remaining patients presented slightly narrower neocord than the vocal fold on the opposite side.

Scar in the anterior commissure and anterior fusion of the vocal folds (synechia/web formation in the anterior commissure)

In all patients from conventional cordectomy groups (D and E) scar or synechia formation in the

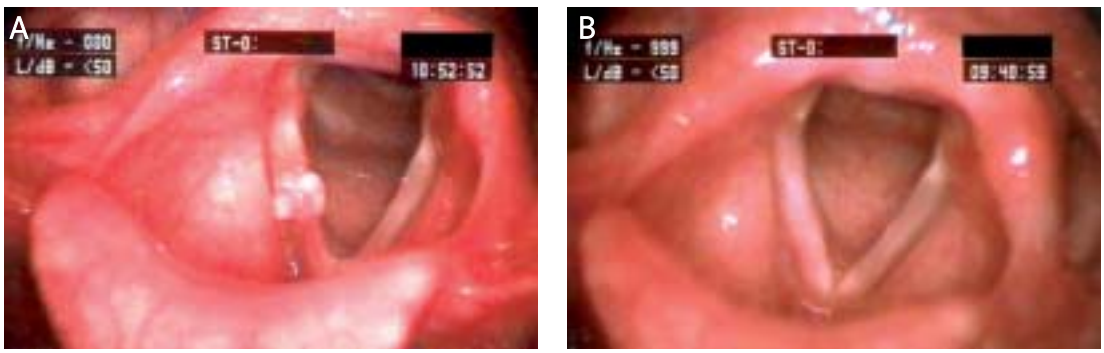

Figure 1. Photos taken during videolaryngoscopic examination of patient who underwent endoscopic laser cordectomy of the right vocal fold: A – before the surgery – the cancer invaded the middle part of the right vocal fold, B – after the surgery – a smooth and straight neocord

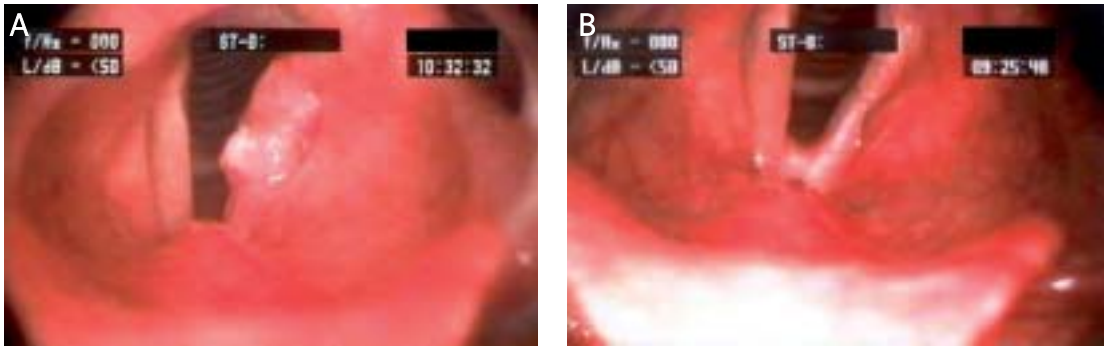

Figure 2. Photos taken during videolaryngoscopic examination of patient who underwent laryngofissure conventional cordectomy of the left vocal fold: A – before the surgery – the cancer invaded almost the entire left vocal fold and was localized close to the anterior commissure, B – after the surgery – a smooth, straight neocord and scar formation in the anterior commissure

Figure 3. Photo taken during videolaryngoscopic examination of patient who underwent endoscopic laser cordectomy of the left vocal fold – a smooth, straight neocord, a scar and a small synechia in the anterior commissure

Figure 4. Photo taken during videolaryngoscopic examination of patient who underwent laryngofissure conventional cordectomy of the right vocal fold – an extensive synechia in the anterior commissure

Figure 5. Photo taken during videolaryngoscopic examination of patient who underwent endoscopic laser cordectomy of the right vocal fold – a smooth, straight neocord on the right and neither scar nor synechia in the anterior commissure

Table II. Presence or absence of scar or synechia in anterior commissure according to method of surgical treatment (conventional or laser cordectomy) with or without additional radiotherapy (n = 46)

Group	Scar in anterior commissure	
	Present (n)	Absent (n)
A	10	9
B	5	6
C	1	–
D	6 + 4 (Extensive synechia)	–
E	5	–
ABCDE	31	15
% of n	67.39	32.61

anterior commissure was observed. Half of the laser cordectomy groups (A and B) presented anterior commissure free of any scar or web. The results are presented in Figures 3–5, and Table II.

Movements of the vocal folds

Forty-five patients (97.83%) presented normal vocal fold movements on respiration and phonation. Reduced movement on both sides of the glottis was

Figure 6. Photo taken during videostroboscopic examination of larynx of patient who underwent endoscopic laser cordectomy of the right vocal fold – complete glottic closure

Figure 7. Photo taken during videostroboscopic examination of larynx of patient who underwent laryngofissure conventional cordectomy of the left vocal fold – complete glottic closure

Figure 8. Photo taken during videolaryngoscopic examination of patient who underwent endoscopic laser cordectomy of the right vocal fold – incomplete glottic closure

Figure 9. Photo taken during videolaryngoscopic examination of patient who underwent laryngofissure conventional cordectomy of the left vocal fold – incomplete glottic closure

observed in 1 patient (2.17%) who had undergone additional radiotherapy (group B).

Difference in level between the neocord and the contralateral vocal fold

The neocord was located at a lower level than the contralateral vocal fold in 6 patients (13.04%); all of them had undergone conventional cordectomy (3 from group D and 3 from group E). In the patient from group C the neocord was located higher than the contralateral vocal fold. The remaining patients (84.78%) presented the neocord and the contralateral vocal fold at the same level.

Glottic closure

In almost all patients from conventional cordectomy groups (D and E) incomplete glottic closure was observed. In laser cordectomy groups (A and B) complete glottic closure was observed in 14 patients, and incomplete in 12. Figures 6–9, and Table III present the results.

Phonation type

The phonation type was evaluated on videolaryngoscopic and videostroboscopic examination. In most of the patients (91.30%) phonation at the glottic level was observed, including all from laser cordectomy groups (A and B). The results are presented in Figures 10–12, and Table IV. The stroboscopic examination allows simultaneous evaluation of the fundamental frequency of phonation and it is considered helpful in examining patients with considerable vestibular folds hyperfunction. In 2 patients from group A and 2 from group D the use of a laryngophone for that purpose was needed (Figure 12).

Table III. Evaluation of glottic closure according to method of surgical treatment (conventional or laser cordectomy) with or without additional radiotherapy (n = 46)

Group	Glottic closure		Impossible to evaluate	
	Complete (n)	Incomplete (n)	Vestibular folds completely covering the glottis during phonation (n)	Vestibular folds covering most of the glottis during phonation (n)
A	9	6	2	2
B	5	6	–	–
C	–	1	–	–
D	–	6	1	3
E	1	2	–	2
ABCDE	15	21	3	7
% of n	32.61	45.65	6.52	15.22

Figure 10. Photo taken during videolaryngoscopic examination of patient who underwent endoscopic laser cordectomy of the right vocal fold – slight vestibular fold hyperfunction during phonation – phonation at the glottic level

Figure 11. Photo taken during videolaryngoscopic examination of patient who underwent laryngofissure conventional cordectomy of the right vocal fold – considerable vestibular fold hyperfunction during phonation – phonation at the vestibular folds level (Fo = 58 Hz)

Figure 12. Photo taken during videolaryngoscopic examination of patient who underwent endoscopic laser cordectomy of the left vocal fold – phonation at the glottic level with considerable vestibular fold hyperfunction during phonation (Fo = 240 Hz)

Vestibular hyperfunction on phonation

The videolaryngoscopic examination revealed absent, slightly marked or considerable hyperfunction of the vestibular folds on phonation (Table V). The vestibular folds coming close or touching each other on phonation (sphincter contraction of the vestibular part of the larynx) was established as considerable vestibular hyperfunction and was observed in almost all patients from conventional cordectomy groups (D and E) and in half from laser cordectomy groups (A and B).

Regularity of vibration

The regularity of vibration of the vocal fold and the tendency to vibration of the neocord were evaluated using videolaryngostroboscopy. A tendency to vibration of the neocord was observed in most patients after laser cordectomy (A and B). Almost all patients from conventional cordectomy groups (D and E) presented no vibration of the neocord. The results are presented in Tables VI, VII.

Mucosal wave

The mucosal wave of the vocal fold on the unoperated side and of the neocord was evaluated

Table IV. Evaluation of phonation type according to method of surgical treatment (conventional or laser cordectomy) with or without additional radiotherapy (n = 46)

Group	Phonation type		
	At the glottic level (n)	Normal vocal fold and vestibular fold on the operated side (n)	At the vestibular folds level (n)
A	19	–	–
B	11	–	–
C	1	–	–
D	8	1	1
E	3	–	2
ABCDE	42	1	3
% of n	91.30	2.17	6.52

Table V. Vestibular hyperfunction on phonation according to method of surgical treatment (conventional or laser cordectomy) with or without additional radiotherapy (n = 46)

Group	Vestibular hyperfunction during phonation	
	Absent or slightly marked (n)	Considerable (n)
A	11	8
B	4	7
C	–	1
D	–	10
E	1	4
ABCDE	16	30
% of n	34.78	65.22

Table VI. Regularity of vibration of vocal fold on phonation according to method of surgical treatment (conventional or laser cordectomy) with or without additional radiotherapy (n = 46)

Group	Vocal fold vibration (unoperated side)		Impossible to evaluate (n)
	Regular (n)	Irregular (n)	
A	16	1	2
B	10	1	–
C	–	1	–
D	7	–	3
E	3	–	2
ABCDE	36	3	7
% of n	78.26	6.52	15.22

Table VII. Tendency to vibration of neocord on phonation according to method of surgical treatment (conventional or laser cordectomy) with or without additional radiotherapy (n = 46)

Group	Tendency to vibrationof neocord		Impossible to evaluate	
	Absent (n)	Present (n)	Vestibular folds completely covering the glottis during phonation (n)	Vestibular folds covering most of the glottis during phonation (n)
A	4	11	2	2
B	4	7	–	–
C	1	–	–	–
D	6	–	1	3
E	2	1	–	2
ABCDE	17	19	3	7
% of n	36.96	41.30	6.52	15.22

using videolaryngostroboscopy. A normal mucosal wave on the unoperated side was observed in 36 patients (78.26%), and slightly reduced in 3 patients (6.52% – they were patients from group B after additional radiotherapy). The results are presented in Table VIII.

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

Table VIII. Mucosal wave of the neocord according to method of surgical treatment (conventional or laser cordectomy) with or without additional radiotherapy (n = 46)

Group	Mucosal wave of the neocord		Impossible to evaluate	
	Absent (n)	Marked in the posterior part (n)	Vestibular folds completely covering the glottis during phonation (n)	Vestibular folds covering most of the glottis during phonation (n)
A	11	4	2	2
B	8	3	–	–
C	1	–	–	–
D	6	–	1	3
E	3	–	–	2
ABCDE	29	7	3	7
% of n	63.04	15.22	6.52	15.22

larger groups (groups A and B together, and groups D and 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 appearance of the neocord, scar or synechia formation in the anterior commissure, glottic closure, phonation type, ventricular hyperfunction, regularity of vibration of the vocal fold on the unoperated side, tendency to vibration of the neocord and the mucosal wave were analysed using the mentioned tests.

The videolaryngoscopic and videolaryngostroboscopic examination showed statistically a considerably higher occurrence of the following findings in the patients after the endoscopic laser cordectomy ($p < 0.05$, Wanke's excess > 1):

1) phonation at the glottic level,
2) complete glottic closure,
3) tendency to vibration of the neocord on phonation.

Ventricular hyperfunction on phonation and scar or synechia formation in the anterior commissure were observed statistically more frequently in patients after laryngofissure conventional cordectomy ($p < 0.05$, Wanke's excess > 1). The remaining evaluated features appeared statistically equal in all analysed groups ($p > 0.05$). The essential statistical results (results with $p < 0.05$ and Wanke's excess > 1) are presented in Table IX.

Discussion

The removal of a vocal fold invaded by glottic carcinoma results in the development of a scar, which takes over the function of the vocal fold. Betlejewski *et al*. reported that after endoscopic laser cordectomy a smooth, pink scar developed. Later after the surgery they noticed that the neocord became thinner and more elastic, which brought the phonatory conditions closer to physiological ones. In the case of extended cordectomy involving anterior commissure removal, the scar became tenser, which influenced the tension of the contralateral vocal fold [9].

Zeitels described his observations concerning scar formation in 1996. It was a retrospective review of microlaryngeal procedures of benign and malignant lesions of the vocal folds. When the superficial lamina propria of the vocal fold is excised as part of the tumour resection, the regenerated epithelium during the healing process becomes adherent to the underlying part of the vocal fold, which causes stiffness. The author did not observe any evidence that after removal, the superficial lamina propria regenerates in the way that epithelium does. However, after this kind of tumour excision the healed neocord is usually straight and smooth, and the glottic closure is complete in most cases. The increased stiffness of the neocord requires higher subglottal pressure to set the vocal folds into vibration. Extensive resection including vocal muscle causes more disorder, which leads to incomplete glottic closure due to the narrow excavated concave neocord. To achieve vocal fold vibration, higher subglottal pressure is needed. Consequently, the voice becomes unstable and the severity of dysphonia is related to the deficit in glottic closure due to the volume of the removed vocal fold tissue [10]. In our study the amount of resected tissue was slightly larger in the case of conventional cordectomy than laser cordectomy. In almost all patients from conventional cordectomy groups incomplete glottic closure and considerable vestibular hyperfunction were observed. In laser cordectomy groups (A and B) complete glottic closure was observed in 14 patients, incomplete in 12, and half of the patients presented considerable vestibular hyperfunction.

Table IX. Wanke's excess for $p < 0.05$ results of the statistical analysis of videolaryngoscopic and videostroboscopic features. The feature is important when Wanke's excess is > 1

Phonation type	Statistical analysis			Wanke's excess	
	At the glottic level	At the ventricular level	Value of *p*	At the glottic level	At the ventricular level
Laser cordectomy	30	0	0.0275	1.07	0.00
Conventional cordectomy	11	3		0.84	3.14
Glottic closure	**Incomplete**	**Complete**	**Value of *p***	**Incomplete**	**Complete**
Laser cordectomy	12	14	0.0483	0.81	1.26
Conventional cordectomy	8	1		1.56	0.26
Ventricular hyperfunction	**Absent or slightly marked**	**Considerably marked**	**Value of *p***	**Absent or slightly marked**	**Considerably marked**
Laser cordectomy	15	15	0.0069	1.41	0.78
Conventional cordectomy	1	14		0.19	1.45
Scar or synechia formation in the anterior commissure	**Absent**	**Present**	**Value of *p***	**Absent**	**Present**
Laser cordectomy	15	15	0.0006	1.50	0.75
Conventional cordectomy	0	15		0.00	1.50
Vibration tendency of the neocord	**Absent**	**Present**	**Value of *p***	**Absent**	**Present**
Laser cordectomy	8	18	0.0049	0.67	1.28
Conventional cordectomy	8	1		1.94	0.20

Earlier, in 1985 Hirano *et al.* reported the relationship between the extent of vocal fold tissue removal and the videolaryngostroboscopic findings. The authors investigated patients after laser cordectomy performed due to glottic carcinoma. They noted that along with greater tissue excision the glottic closure became more frequently incomplete, the amplitude of vibration of the neocord became reduced, and the mucosal wave on that side was more likely absent [11]. Similar observations were made by Casiano *et al.*, Peretti *et al.*, and Krengli *et al.* [12-14]. In our study the tendency to vibration of the neocord was observed in most patients after laser cordectomy. Almost all patients after conventional cordectomy presented no vibration of the neocord.

Jurkiewicz *et al.* reported that dysphonia is more likely to appear in patients after more extensive resection of the vocal fold and in the case of a second surgery in the glottis [15, 16]. Remacle *et al.* also concluded that extensive loss of vocal fold tissue after cordectomy considerably influences the videostroboscopic outcomes [17].

The comparison of vocal function following endoscopic laser cordectomy and conventional surgery of malignant vocal fold tumours was presented by Keilmann *et al.* Videolaryngostroboscopy revealed that after laser surgery phonation was statistically more often at the glottic level (81%) compared to conventional cordectomy (19%). Synechia in the anterior commissure was more often observed in patients after conventional surgery [18]. In our study in all patients after conventional cordectomy and in half after laser cordectomy, scar or synechia formation in the anterior commissure was observed. In most of the patients (91.30%) phonation at the glottic level was observed, including all from laser cordectomy groups.

In conclusion, in our study, the videolaryngoscopic and videolaryngostroboscopic examination showed statistically a considerably higher occurrence of the following findings in patients after endoscopic laser cordectomy: phonation at the glottic level, complete glottic closure, and a tendency to vibration of the neocord on phonation. Ventricular hyperfunction on phonation and scar or synechia formation in the anterior commissure were observed statistically more frequently in patients after laryngofissure conventional cordectomy. The reason for those findings may be the amount of the excised tissue within the glottis that was slightly larger in patients after conventional surgery. In those patients also the fact of the laryngofissure and the following fusion of the thyroid cartilage in the midline more often results in a difference in level between the neocord and the contralateral vocal fold, and scar or synechia formation in the anterior commissure. Those features play an important role in the phonatory patterns after the surgery.

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