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ORIGINAL ARTICLE

Voice quality after laser cordectomy and vertical hemilaryngectomy

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Voice;
Acoustic analysis;
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Abstract *Introduction:* Various surgical techniques have been adopted for management of glottic cancer with the aim of eradicating the disease and preserving the voice character.
Aim: The aim of the study was to determine the voice quality for patient after various surgical interventions for treatment of cancer larynx, and to evaluate the effect of postoperative voice therapy.
Subjects: 20 patients were subjected to surgical intervention for management of glottic cancer (seven had unilateral laser cordectomy-group A, and five had bilateral laser cordectomy-group B and eight had vertical hemilaryngectomy-group C). Thirteen age matched males were randomly selected for obtaining normal computer voice function parameters as the control group-group D.
Methodology: The four groups were subjected to protocol of voice evaluation postoperatively. Patients were re-evaluated two months later and a comparison of voice outcome for patients receiving voice therapy and those who did not was conducted.
Conclusion: Most acoustic and aerodynamic parameters are significant different between patients from control. Subharmonics parameters (NSH and DSH) and degree of voice breaks (DVB) in addition to phonatory resistance specifically differentiate the voice of laser cordectomized from that of vertical hemilaryngectomized patient, this may reflect occurrence of vocal fry related to supraglottic phonation. Improvement was recorded by all patients receiving voice therapy. Unilateral laser

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cordectomy gave better phonatory outcome due to less extension of surgical resection and development of glottic phonation. Bilateral laser cordectomy gave relatively worse prognosis highlighting the advantage of the experience of surgeon in creation of pseudoglottis in improving phonatory outcome in vertical hemilaryngectomy over extensive resection of bilaterally cordectomized patients.

1. Introduction

Treatment of laryngeal cancer aims basically at eradication of the disease, and then preservation of voice after intervention is carried out. Thus, if this could be achieved an extreme success of intervention would be reached. Preservation of the regular phonation is an important consideration at the time of selecting the treatment of a laryngeal cancer at initial stages. Endoscopic laser resection, open partial surgery and external radiotherapy, with local control figures of 80–90%,[1] are satisfactory used in management of glottic T1 and T2. The out coming voice quality after treatment is an important factor to take into consideration at the time of evaluating the results,[2] especially that early glottic cancer usually presents with change of voice and in most patients, hoarseness is the only complaint. Post-treatment voice quality is therefore an important parameter in determining the efficiency of variable surgical techniques.

The grade of dysphonia depends on the type of cordectomy, which in turn is dependent on the type and volume of tissue removed. Remacle et al.[3] proposed a cordectomy staging using CO2 laser which involved type I–III with type I similar to that suggested by Eckel and Thumfart,[4] who indicated that type I involves decortication. Remacle's type II is removal of vocal fold from the vocal process to the anterior commissure and passing through the inferior thyroarytenoid muscle, while in type III vocal fold is resected along the internal side of the thyroid ala. In type IIIB the anterior commissure is additionally removed. Laser cordectomies are not simple operations and require considerable experiences in endoscopic microsurgery. They tend to cause less pain and no tracheostomy is required. In type I cordectomy only the epithelium is resected. In the type II and type III cordectomies, the quality of voice depends on the development of a fibrous fold and the absence of anterior synechae in the healed larynx.[5] The European laryngological society in 2000 established a detailed classification for laser cordectomy which took into consideration the depth and anteroposterior extent of resection.[3]

For larger glottic carcinomas with extension to the vocal process or involvement of the ventricle, or for transglottic lesions without cord fixation, vertical hemilaryngectomy can be used. In standard hemilaryngectomies, the thyroid cartilage is cut in the center to allow entry into the laryngeal lumen at the anterior commissure. The resection specimen includes most of the true vocal fold, the overlying thyroid cartilage, and the involved false vocal fold. Subglottic extension of more than 10 mm anteriorly or 5 mm posteriorly, lesions with invasion of the cricoarytenoid joint, are contraindication for vertical partial laryngectomy. In addition interarytenoid region, thyroid cartilage, or both arytenoids should not be removed via hemilaryngectomy. Vocal fold fixation is a relative contraindication, depending on the cause of the fixation and tumor size.[3] Variations from the classical vertical hemilaryngectomy include the frontolateral, posterolateral, and extended hemilaryngectomies. In cases of bilateral lesions in which the tumor involves the anterior commissure, the frontolateral vertical partial laryngectomy can provide an increased extent of resection by moving the vertical thyrotomy from the midline toward the less involved side. In the posterolateral vertical hemilaryngectomy, the entire endolaryngeal circumference except for one arytenoid region and the posterior commissure can be removed. The extended vertical hemilaryngectomy removes the superior aspect of the cricoid cartilage.[6] Many authors have reported excellent survival results with their vertical partial laryngectomy experiences. Olsen and DeSanto[7] reported that their use of vertical partial laryngectomies produces better patient survival in comparison to radiation therapy.

All types of small vocal fold tumor therapy allow preservation of respiration and deglutition but lead to a worsening of the voice. Phonation quality is considered the most important criterion of success.[2] The best surgical techniques never results in the same voice as that of healthy people. Good result is properly achieved when the voice quality after the operation is similar to the voice quality before the operation.[8] Post-treatment voice results can have significant impact on the patient's quality of life and his ability to maintain employment.[2] The phonatory mechanism adopted by the patients after surgery is the most important factor in determining the quality of the new voice. Smith et al.[9] classified voicing mechanism used to evaluate phonation mechanisms into (1) purely glottic, (2) glottic with incomplete closure, (3) glottic with false fold compression, and (4) glottic with anterior–posterior supraglottic compression.

Postoperative voice rehabilitation has to be assessed in every patient because well-directed voice therapy is helpful in the acquisition of the most effective phonatory mechanism.[10] Voice production at the level of the glottis and preservation of the anterior commissure during surgery are the most important parameters in determining the mechanism of phonation and the ability to communicate effectively post-surgically.[11] Quantitative acoustic measurements are more regularly studied and these are obtained from tools that digitalize and analyze the deviance from normality and facilitate when to judge voice as uniform as regards tone, periodicity and amplitude and indicate abnormality as addition of noise signal to voice which also affect voice quality.[12]

1.1. Rationale of the study

Various surgical techniques have been adopted for management of glottic cancer with the aim of eradicating the malignant changes and preserving the voice character. Researchers commonly direct their studies to indicate the effectiveness of one technique over the other, but only few concentrated on documenting acoustic combined with aerodynamic changes in indicating the advantage of these techniques and in objectively discussing the effectiveness of voice therapy.

1.2. The aim of the study

The aim of the study was to evaluate the voice quality for patient after laser cordectomy and vertical hemilaryngectomy for treatment of cancer larynx, and to evaluate the effect of postoperative voice therapy on the voice outcome.

1.3. Subjects

Twenty male patients having glottic carcinoma treated at the department of Otolaryngology Head and Neck surgery and unit of phoniatrics, University of Alexandria, Egypt were included in the study. Twelve patients had laser cordectomy (7 "T1" = Group A unilateral, and 5 "T2" = Group B bilateral), 8 "T2" patients had vertical hemilaryngectomy (Group C). All patients were subjected to the protocol of voice evaluation. This was conducted before voice therapy and after at least 12 session of therapy. All patients were followed up regularly. For the purpose of obtaining norm references, acoustic and aerodynamic measurement of 13 ages matched non-dysphonic males (Group D) were recorded.

1.4. Methodology

All participants were subjected to voice evaluation following the protocol of voice assessment[13] carried out at the Unit of Phoniatrics (University of Alexandria Egypt) this includes:

1.5. Elementary diagnostic procedures included

1. Patient's interview, including personal data, analysis of the complaints especially following surgical intervention. The effect on patients subjective impression of the voice was noted. This was graded from zero (no change from habitual voice quality) to four indicating extreme change from habitual voice quality. Grade 1, 2, and 3 represents mild moderate and severe degree of change.
2. Auditory perceptual assessment was carried out using a modified scale as adopted by Kotby (1986), with four grades from zero (normal) to three (severe dysphonic). G = overall grade, R = rough, B = breathy, S = strained and L = leakiness.[13]

1.5.1. Clinical diagnostic aids

Augmentation and documentation of the glottis using: Endoscopic and stroboscopic examination which was videotaped for further review, and examination.

1.6. Additional diagnostic measures

1. *Acoustic analysis: Using* Multi Dimensional Voice Program (MDVP) of Kay Elemetrics Cooperation. The following parameters are selected:
   - Average, highest and lowest fundamental frequency (Fo, Fhi, Flo) in Hz, phonatory frequency range (PFR). Measures of frequency perturbation as Absolute jitter in μsec(jita). Jitter percent (Jitt). Relative average (RAP), pitch period (PPQ) and smoothed pitch perturbation quotients (sPPQ). Also coefficient of fundamental frequency percent (vFo). Amplitude perturbation analyzes includes shimmer in dB (ShimdB), shimmer percent (Shim). Amplitude (APQ) and smoothed amplitude perturbation quotients (sAPQ) and coefficient of amplitude variation percent (vAm).
   - Voice break analysis measured by degree of voice breaks and number (DVB, NVB), voiceless (DUV, NUV) and subharmonics (DSH, NSH).
   - Noise related analysis as noise to harmonic ratio (NHR), voice turbulence and soft phonation indices (VTI, SPI).
   - Tremor analysis included fundamental tremor frequency (Fftr) and intensity index (FTRI). Amplitude tremor frequency (Fatr) and intensity index (ATRI)
2. *Aerodynamic measures:* Phonatory aerodynamic measurements were done using Voice Function Analyzer Aerophone II software Model 6800 (Kay Elemetric 2001) and the associated software. The aerodynamic parameters included: Vital capacity (VC), maximum phonation time (MPT), phonatory quotient (PQ), phonatory speech pressure level, phonatory flow rate, mean air pressure, Glottal efficiency (GE) and Glottal resistance (GR).

1.7. Clinical and operative details

Laser cordectomy was carried according to the European Laryngological Society proposal for classification of types of laser cordectomy 2000.[5] The five patients underwent type IV bilateral Laser cordectomy, and 7 patients underwent type III (transmusclar) unilateral laser cordectomy. The other 8 patients underwent vertical hemilaryngectomy according to Bailey's technique (1975)[14] using the sternomastoid muscle for reconstruction of the defect inside the ipsilateral thyroid perichondrium (three right and five left side of the larynx). Postoperatively all patients received inhalational mitomycin-C (MMC) 0.5 ml of 0.5 mg in saline (0.125 mg) delivered through an electronic nebulizer). MMC was delivered/8 h on the first week, 12 hourly on the second and third weeks and once daily for another two weeks. The aim of MMC as previously reported[14] was to minimize the postoperative granulation tissue and fibrosis, providing the best chances for healing

1.8. Voice therapy details

Accent method was applied by all cases for at least 12 sessions twice/ week for a period of half an hour. It consists of:

- Optimal abdominodiaphragmatic breathe support.
- Rhythmic play of accentuated relaxed vowels with progressive carry over to connected speech.
- Dynamic rhythmic body and arm movements.

For patients presented with aphonia or marked voice break, extra methods were used as visual feedback with computerized tools or manual manipulation of the larynx. Relaxation exercises for head and neck were used when needed.

1.9. Statistical analysis

Categorical data obtained were analyzed using non-parametric Mann–Whitney test (z), to compare expression in the two subsite groups. The Wilcoxon signed-ranks test was applied to two-sample designs involving repeated measures "before" and "after" measures. Dunnett's test was used to compare group means pitted against control group. All statistical analyzes were performed using the SPSS software package, ver. 13.0. P values less than 0.05 were considered significant.

2. Results

The mean age of the patients and control was 53.61 ± 7.676, with a (range from 44 to 70 years) and 55.1 ± 9.267 (range from 34 to 75 years) respectively. No statistical difference between both groups as regards age was found ($p = .592$)

2.1. Patient's subjective impression on voice

Following surgical intervention for glottic cancer, all patients were not satisfied with their voice quality and the patients rating of their subjective degree of change of voice ranged from two to four. Twelve patients reported severe degree (3) of voice change, five reported a moderate degree (2) of change and three indicated extreme degree (4) of voice deviance from normal.

2.2. Auditory perceptual assessment

Table 1 summarizes the auditory perceptual assessment for the three groups of the patients. No specific pattern could be subtracted except that voice break and vocal fry were recorded in most patients.

2.3. Acoustic analysis and aerodynamic measures deviance from control group

The patients have shown significantly elevated values than the control group in all parameters except the lowest fundamental frequency (Flo) (lower in patients than control), soft phonation and voice turbulence indices (SPI, VTI) (Table 2). All tremor analysis parameters have shown no significant difference. Aerodynamic measures have shown lowering of vital capacity (VC), maximum phonation time (MPT), phonatory efficiency and resistance for patients than control. There was no significant difference between both groups except in maximum phonation time, phonatory efficiency and phonatory resistance (Table 3).

2.4. Acoustic and aerodynamic outcome of various surgical procedures

Parameters showing no significant difference between patients and control were eliminated from the rest of analysis. Acoustic measures revealed no significant difference between the voice of the patients undergoing vertical hemilaryngectomy (Group C) and patients with laser cordectomy (Group A and Group B) except in DVB, NVB and NUH. The majority of parameters were relatively higher for vertical hemilaryngectomy except PFR, sPPQ, shdB, APQ, and DUV that recorded higher values in laser cordectomy (Table 4).

Comparison of acoustic parameters between patients subjected to unilateral laser cordectomy (Group A) and those with bilateral laser cordectomy (Group B) revealed a tendency for the values to be higher in patients with bilateral cordectomy group except Fo and DVB with statistical significant difference recorded at NVB ($z = -2.558$, $p = .011$) and NVB ($z = -2.254$, $p = .024$) (Table 5). Comparison between unilateral

Table 1 Shows auditory perceptual assessment (APA) of the patients at first visit and follow up visit.

Auditory perceptual assessment (APA)	Unilateral cordectomy group A	Bilateral cordectomy group B	Vertical hemilaryngectomy group C	Total
Intensity				
Excessive	3	5	2	10
Decreased or aphonic	1	2	3	6
Average	2	2	0	4
Overall grade of voice change				
1	0	1	1	2
2	2	2	2	6
3	3	4	3	10
Strained				
1	1	1	0	2
2	0	3	2	5
3	3	3	3	9
Leaky				
1	1	1	0	2
2	0	3	2	5
3	2	2	3	7
Roughness				
1	0	0	0	0
2	3	0	3	6
3	3	3	4	10
Vocal fry	3	1	5	9
Voice break	4	3	5	12

Table 2 Multidimensional voice profile for studied patients and control.

	Patients (group A, B & C) (n = 20)	Normal (group D) (n = 13)	z-value	p
Frequency measures				
Fo	159.29 ± 57.95	118.5 ± 23.11	−0.84	.005
Fhi	228.46 ± 137.52	124.94 ± 24.95	−3.28	.003
Flo	111.54 ± 38.53	112.33 ± 22.57	−0.63	.531
STD	25.76 ± 34.35	1.57 ± 0.57	−3.87	.000
PFR	12.25 ± 10.42	3.00 ± 1.41	−3.87	.001
Tremor analysis measures				
Fftr	4.14 ± 2.75	4.14 ± 2.45	−0.57	.567
Fatr	4.81 ± 5.37	2.73 ± 0.815	−0.05	.962
FTRI	1.57 ± 1.76	0.53 ± 0.23	−1.30	.194
ATRI	7.57 ± 7.63	3.75 ± 2.66	−1.56	.118
Frequency perturbation measures				
Jita	312.09 ± 221.39	77.44 ± 27.16	−4.05	.000
Jitt	5.19 ± 3.47	0.89 ± 0.42	−4.31	.000
RAP	2.99 ± 1.96	0.534 ± 0.268	−4.31	.000
PPQ	3.34 ± 2. 37	0.516 ± 2.45	−4.31	.000
sPPQ	6.44 ± 7.34	0.86 ± 2.77	−4.44	.000
vFo	13.65 ± 15.09	1.35 ± 0.45	−3.91	.000
Amplitude perturbation measures				
ShdB	1.22 ± .90	0.27 ± 0.097	−4.24	.000
Shim	13.65 ± 9.49	3.12 ± 1.18	−4.22	.000
APQ	9.80 ± 7.17	2.47 ± 0.81	−4.42	.000
sAPQ	12.06 ± 7.50	4.37 ± 1.35	−3.72	.000
vAm	19.66 ± 9.66	12.00 ± 5.40	−2.72	.018
Noise related parameters				
NHR	0.31 ± 0.245	0.15 ± 0.21	−2.20	.028
VTI	0.13 ± 0.17	0.05 ± 0.04	−1.37	.169
SPI	26.38 ± 16.36	35.13 ± 25.43	−1.10	.269
Voice break, voiceless segments and subharmonic measures				
DVB	42.76 ± 172.79	0 ± 0	−2.46	.014
DSH	4.79 ± 6.61	0 ± 0	−2.55	.011
DUV	30.36 ± 38.57	0.09 ± 0.32	−3.30	.001
NVB	1.65 ± 3.06	0 ± 0	−317	.002
NSH	2.66 ± 5.07	0 ± 0	−2.41	.016
NUV	14.55 ± 26.16	0.77 ± 0.28	−2.84	.004

Significant $p \leqslant .05$.

Table 3 Aerodynamic changes for patients and normal.

	Patient (n = 20)	Control (n = 13)	z-value	p
Vital capacity	2.84 ± 1.60	3.67 ± 1.06	−1.46	.145
MPT	9.64 ± 5.47	17.15 ± 4.58	−3.14	.002
Phonatory quotient	0.44 ± 0.36	0.22 ± 0.86	−1.41	.159
Phonatory flow rate	0.93 ± 1.21	0.32 ± 0.27	−1.83	.069
Phonatory SPL	84.46 ± 9.63	77.29 ± 13.29	−1.21	.224
Mean air pressure	9.28 ± 5.32	7.25 ± 3.16	−0.08	.934
Phonatory efficiency	0.411 ± 0.77	118.20 ± 127.19	−1.74	.000
Phonatory resistance	17.07 ± 6.69	51.26 ± 54.05	−4.24	.049

Significant $p \leqslant .05$.

laser cordectomy (Group A) and vertical hemilarygectomy (Group C) revealed statistical significant difference in DSH (z = −2.510, p = 0.012) and the NSH (−2.972, p = 0.003). Furthermore significant difference between bilateral laser cordectomy (Group B) and vertical hemilaryngectomy (Group C) as regards DSH (z = −2156, p = 0.31) only was recorded.

Aerodynamic parameters were lower in laser cordectomy (Group A and B) than vertical hemilaryngectomy patient (group C) except in maximum phonation time and phonatory efficiency, a statistical significant difference was recorded in phonatory resistance only (z = −1.21, p = .007) (Table 6).

Table 4 Multidimensional voice profile and aerodynamic measures for vertical hemilaryngectomy and laser cordectomy.

	Vertical hemilaryngectomy (group C) (n = 8)	Laser cordectomy (n = 13) group A & B	z-value	p
Frequency measures				
Fo	181.10 ± 72.60	148.32 ± 40.60	1.93	0.185
Fhi	243.89 ± 160.01	211.38 ± 101.83	0.26	0.617
STD	27.16 ± 39.17	21.23 ± 28.60	0.08	0.778
PFR	10.65 ± 8.57	11.40 ± 11.10	0.59	0.453
Frequency perturbation measures				
Jita	366.03 ± 297.16	346.13 ± 253.33	0.05	0.818
Jitt	5.57 ± 3.21	4.88 ± 3.60	0.51	0.485
RAP	3.17 ± 1.73	2.84 ± 2.07	1.30	0.271
PPQ	3.47 ± 2.15	3.68 ± 2.87	2.26	0.153
sPPQ	6.55 ± 7.53	7.30 ± 9.63	0.54	0.474
vFo	12.15 ± 11.71	9.84 ± 13.60	0.60	0.809
Amplitude perturbation measures				
ShdB	1.28 ± 0.83	4.11 ± 9.95	3.07	0.099
Shim	14.13 ± 8.84	11.83 ± 9.12	0.63	0.439
APQ	9.92 ± 7.00	10.28 ± 8.69	1.56	0.230
sAPQ	10.81 ± 6.45	13.69 ± 9.37	1.80	0.198
vAm	19.68 ± 8.10	17.61 ± 11.85	2.13	0.164
Noise related parameters				
NHR	0.31 ± 0.21	0.27 ± 0.24	0.27	0.608
Voice break, voiceless segments and subharmonic measures				
DVB	13.28 ± 22.05	2.72 ± 6.44	6.58	0.021
DSH	10.00 ± 7.22	1.58 ± 3.33	3.57	0.076
DUV	30.28 ± 42.02	31.12 ± 40.00	0.03	0.860
NVB	3.37 ± 4.41	0.50 ± 0.53	29.19	0.000
NSH	6.37 ± 6.80	0.60 ± 1.96	13.93	0.002
NUV	17.62 ± 29.61	10.80 ± 15.14	0.67	0.426
Aerodynamic changes parameters				
MPT	8.75 ± 4.79	11.11 ± 6.07	0.68	0.456
Phonatory efficiency	0.13 ± 0.123	0.45 ± 1.10	−0.26	0.126
Phonatory resistance	17.26 ± 5.32	16.92 ± 7.13	−1.21	0.007

Significant $p \leqslant .05$.

Endoscopic examination: showed glottic phonation in two of the patients, and glottic with incomplete closure type was used by another two patients. The rest of the patients showed phonation at the glottic level with false vocal fold compression. All vertically hemilaryngectomatized patients developed a false vocal fold compression type, while one unilateral laser cordectomy patient developed a glottis type of phonation. The rest of them developed glottic with incomplete closure**.** All bilaterally cordectomized patient had glottis level of phonation with incomplete closure.

Reevaluation of subjects: Thirteen patients came for follow up visit. Five patients received no voice therapy (two unilateral laser cordectomized, and three vertically hemilaryngectomized) and reported no change in the **subjective impression of voice quality** compared to preoperative subjective impression. The **auditory perceptual assessment** also showed no change except in one vertically hemilaryngectomized patient who revealed worsening of voice quality as regards overall grade of dysphonia with evident roughness of voice with persistence of vocal fry and voice breaks, extreme lowering of voice intensity. **Endoscopic examination** revealed development of anterior synechea in this patient. **Pre and postacoustic and aerodynamic measures** of those who did not receive voice therapy revealed no statistically significant change (Table 6).

2.5. Outcome of voice therapy

Eight patients only completed the voice therapy program. They reported moderate or no response except for one patient who reported a good response, but all felt still handicapped following the voice therapy. Three patients only revealed an **auditory perceptual assessment** of overall grade of dysphonia two rather than three following voice therapy. All patients complaining of aphonia or decreased voice loudness have reported improvement and satisfaction with their voice loudness. It was noticed that following voice therapy most of the patients were able to eliminate the vocal fry and avoid voice breaks. Better control of the voice loudness was noticed. **Endoscopic examination** showed that glottis phonation was developed by two patients, one patient acquired glottis phonation with incomplete closure while the rest showed glottis level phonation with false vocal fold compression.

The acoustic analysis revealed lowering of values of all parameters. Statistical significant difference was recorded in Fhi, PFR, jita, jitt, RAP, PPQ, APQ, sAPQ, DUV, DVB parameters in addition to phonatory efficiency and resistance (Table 6). It was noticed that patients with unilateral laser cordectomy gave the best results when compared to the normal measurers (Table 7).

Table 5 Multidimensional voice profile aerodynamic measures for unilateral and bilateral cordectomy.

	Unilateral laser cordectomy group A (n = 7)	Bilateral laser cordectomy group B (n = 5)	p
Frequency measures			
Fo	146.771 ± 47.84	141.94 ± 41.17	.866
Fhi	188.16 ± 93.46	260.21 ± 149.26	.167
STD	19.94 ± 32.24	31.68 ± 35.3	.084
PFR	9.00 ± 10.26	17.2 ± 14.34	.053
Frequency perturbation measures			
Jita	265.28 ± 215.39	475.76 ± 289.79	.057
Jitt	4.00 ± 3.81	6.23 ± 3.64	.124
RAP	2.37 ± 2.22	3.59 ± 2.09	.489
PPQ	2.52 ± 2.54	3.96 ± 2.85	.271
sPPQ	3.88 ± 4.37	9.84 ± 10.122	.567
vFo	10.9 ± 15.09	19.91 ± 20.82	.809
Amplitude perturbation measures			
ShdB	0.98 ± 1.10	1.45 ± 0.823	.132
Shim	10.76 ± 11.6	17.74 ± 6.76	.542
APQ	8.05 ± 7.95	12.06 ± 7.23	.561
sAPQ	11.12 ± 8.27	15.36 ± 8.36	.187
vAm	18.71 ± 10.14	22.07 ± 12.87	.178
Noise related parameters			
NHR	0.23 ± 0.22	0.43 ± 0.34	.067
Voice break, voiceless segments and Subharmonic measures			
DVB	2.94 ± 7.79	1.68 ± 1.72	.145
DSH	1.13 ± 2.98	1.58 ± 3.53	.802
DUV	24.47 ± 40.62	38.76 ± 36.69	.357
NVB	0.28 ± 0.49	0.80 ± 0.48	.011
NSH	0.00 ± 0.00	1.2 ± 2.68	.237
NUV	0.43 ± 0.77	29.4 ± 32.76	.024
Aerodynamic parameters			
MPT	11.17 ± 6.46	8.25 ± 5.34	.157
Phonatory efficiency	0.83 ± 1.11	0.09 ± 0.87	.055
Phonatory resistance	17.06 ± 9.41	16.85 ± 5.13	.167

Significant $p \leqslant .05$

3. Discussion

Studies of voice quality following treatment of glottic cancer were directed to the use perceptual and quantitative analysis. Although there is no agreement between the phoniatricians with regard to which of these methods is the more useful to assess the voice quality, perceptual evaluation is suggested to be more adequate to assess the habitual voice, whereas the quantitative analysis gives more information on the physiopathology of the vocal defect; thus, they are complementary to each other.[15] For quantitative assessment of voice quality, clinician use aerodynamic and acoustic analysis.[16]

Bertino et al.[8] indicated lowering of Fo in patients with cordectomy whereby in the present study lower values were obtained for non-dysphonic subjects. Increased Fo in our studied group may be due to inclusion of all patients subjected to laser cordectomy or vertically hemilaryngectomy especially that patients with vertical hemilaryngectomy showed higher Fo values in further comparisons. Slightly elevated Fo values were also noticed in Schindler study[16] following laser cordectomy. Increased Fo and Fhi could possibly be explained by the stress and tenseness of external laryngeal muscles that indirectly act on the cricothyroid joint to alter the tension of the vocal fold. This tension is subconsciously adapted postoperatively to avoid pain and discomfort by fixation of the larynx. Decreased Fo noticed postvoice therapy reinforces the relaxation effect on external laryngeal musculature achieved by voice therapy.

Voice outcome is also affected by patients' mechanism of phonation. On videolaryngoscopy, it was noticed that patients with high fundamental frequency use glottic level more often, which suggests that supraglottic mechanism tends to lower fundamental frequency. An interpretation that is not contradictory to the present research finding considering that additional factors are involved[8] as smoking effect on voice quality and preoperative habitual voice and vocal use preoperatively with possible additional hyperfunctional elements. The sampling procedure used in the present study may also affect interpretation of the results since sustained phonation using/a/sound may results in higher pitch.

Fibrosis that results from surgical intervention affect laryngeal musculature, vocal muscles, vocal fold cover cause rigidity of these structures and decrease capacity to modify quickly causing increased perturbation measures.[3] In the present work, the degree of resection in cordectomized patients related to laterality of cordectomy thus was difficult to study separately. Also, increased perturbation measures and voice breaks, voice subharmonic, and unvoiced segment measures was expected

Table 6 Multidimensional voice profile and aerodynamic analysis pre and posttherapy and at initial visit and reevaluation for patients who did not receive voice therapy.

	Therapy (n = 8)			No therapy (n = 5)		
	Prevoicetherapy	Postvoicetherapy	p	Initial visit	Reevaluation	p
Frequency measures						
Fo	149.49 ± 25.47	138.81 ± 54.67	.484	165.83 ± 72.60	199.35 ± 58.73	.715
Fhi	244.14 ± 110.04	164.13 ± 85.62	.036	218.015 ± 157.04	247.43 ± 39.75	.715
STD	25.57 ± 30.225	23.65 ± 47.03	.463	52.07 ± 38.17	32.59 ± 45.34	.715
PFR	14.25 ± 12.39	6.75 ± 7.21	.018	10.92 ± 9.22	7.50 ± 4.95	.593
Frequency perturbation measures						
Jita	365.4 ± 286.40	182.28 ± 153.93	.069	276.51 ± 206.77	354.85 ± 271.35	.144
Jitt	6.12 ± 3.68	2.79 ± 1.83	.012	4.59 ± 3.34	3.94 ± 2.09	.715
RAP	3.62 ± 2.12	1.65 ± 1.07	.012	2.58 ± 1.81	2.56 ± 2.47	.715
PPQ	3.78 ± 2.18	1.76 ± 1.27	.018	3.07 ± 2.25	2.45 ± 1.31	.593
sPPQ	7.75 ± 8.43	3.17 ± 4.36	.069	5.56 ± 6.77	2.80 ± 1.89	.715
vFo	16.94 ± 18.57	8.49 ± 16.47	.208	11.46 ± 12.68	5.45 ± 3.43	.715
Amplitude perturbation measures						
ShdB	1.42 ± 1.06	0.67 ± 0.29	.063	1.08 ± 0.80	0.99 ± 1.01	.715
Shim	15.12 ± 11.09	7.68 ± 3.29	.093	12.58 ± 8.54	10.99 ± 11.51	.715
APQ	10.57 ± 7.34	5.53 ± 2.46	.050	9.29 ± 7.34	7.96 ± 8.18	.715
sAPQ	13.13 ± 7.79	6.80 ± 2.22	.036	11.34 ± 7.56	8.63 ± 7.20	.715
vAm	18.84 ± 9.83	14.96 ± 2.89	.401	20.67 ± 9.91	22.22 ± 18	.465
Noise related parameters						
NHR	0.36 ± 0.29	0.19 ± 0.13	.042	0.27 ± 0.21	0.22 ± 0.18	.465
Voice break, voiceless segments and subharmonic measures						
DVB	42.51 ± 44.09	0.49 ± 1.13	.273	68.84 ± 22.87	65.34 ± 33.00	.317
DSH	0.62 ± 0.52	3.68 ± 4.9	.893	5.04 ± 6.60	6.00 ± 6.44	.317
DUV	3.28 ± 6.45	6.93 ± 13.36	.043	22.27 ± 33.96	25.75 ± 43.88	.465
NVB	27.12 ± 36.74	0.125 ± 0.353	.046	2.33 ± 3.84	0.25 ± 0.50	1.00
NSH	0.625 ± 1.78	0.625 ± 1.78	.285	2.30 ± 4.36	3.20 ± 3.60	.180
NUV	0.00 ± 13.30	0.00 ± 13.30	.115	6.17 ± 11.48	18.50 ± 35.03	.465
Aerodynamic parameters						
MPT	8.75 ± 4.34	12.22 ± 3.93	.059	10.83 ± 6.97	10.00 ± 5.77	.317
Phonatory efficiency	0.67 ± 0.95	276.9 ± 128.3	.028	0.05 ± 0.04	22.91 ± 2.30	.285
Phonatory resistance	16.8 ± 5.20	24.41 ± 32.33	.027	18.46 ± 8.84	27.45 ± 33.59	.180

Significant $p \leqslant .05$

due to irregularity of mucosal edges, irregular glottic gap and closure as a consequence of operation. These findings were more pronounced in vertical hemilaryngectomatized patients. Additionally, significant higher values of DVB and NVB and NSH relates to compensatory techniques acquired in case of vertical hemilaryngectomy for phonation development after an extensive operation it reflects the use of false vocal fold in phonation and associated vocal fry. This finding is emphasized by further comparison of unilateral and bilateral laser cordectomy to vertical hemilaryngectomy whereby the perturbation measurements were the worst in bilateral laser cordectomy than vertical hemilaryngectomy. This concludes roughly that symmetricity of mucosal wave is a basic stone for regularity of voice quality especially in the presence of extensive resection. Glottic phonation with incomplete closure in addition to the presence of incomplete closure had addition impact on worsening of voice quality.

Studies indicate that MPT may be a good indicator of functional results[8] the present study revealed no difference between surgical groups in aerodynamic measurements. Remacle[5] study revealed that the MPT was on the average 12 seconds for laser cordectomy irrespective of type and was not linearly related to degree of cordal operation. The aerodynamic measurers reflecting more physiopathological background of voice production revealed significant difference between vertical hemilaryngecotomy and laser cordectomy as regards phonatory efficiency and resistance as vertical hemilaryngectomy was associated with developing pseudoglottic causing changes in these parameters.

It has been advised to start early voice therapy to guide the acquisition of a good phonatory control and prevent ankylosis of the arytenoids. The present study highlights that significant differences changes occurring in patients receiving voice therapy, when compared to the benefit of patients who did not. Perceptually the vocal fry and voice breaks were noticed in large number of patients and were eliminated in most of patients that received voice therapy.

Voice therapy improved the perturbation measures and the ability to control voice production with adequate glottic closure. No significant difference in any of the parameters in patients that did not receive voice therapy was noticed. Further comparisons revealed that patients with unilateral laser cordectomy, gave better results because of their ability to adopt glottic phonation postoperatively and less extensive degree of resection. It has been reviewed that voice is permanently affected in vertical hemilaryngectomy, whereby

Table 7 Mean values of acoustic and aerodynamic parameters of posttherapy in the three surgical groups and the control.

	Normal (group D) (n = 13)	Unilateral cordectomy (n = 3)	p	Bilateral cordectomy (n = 3)	p	Vertical hemilaryngectomy (n = 2)	p
Frequency measures							
Fo	118.5 ± 23.11	166.11 ± 66.02	.199	218.37 ± 79.82	.012	135.38 ± 64.90	.897
Fhi	124.94 ± 24.95	144.37 ± 36.95	.915	265.63 ± 112.50	.009	189.64 ± 130.60	.251
STD	1.57 ± 0.57	26.89 ± 48.45	.351	43.48 ± 65.94	.098	11.45 ± 8.38	.929
PFR	3.00 ± 1.41	3.00 ± 2.53	.982	10.33 ± 11.85	.035	8.50 ± 4.20	.087
Frequency perturbation measures							
Jita	77.44 ± 27.16	145.87 ± 100.47	.623	166.28 ± 68.00	.576	403.35 ± 283.57	.000
Jitt	0.89 ± 0.42	1.80 ± 0.97	.294	3.40 ± 1.66	.004	4.71 ± 1.99	.000
RAP	0.53 ± 0.27	1.05 ± 0.57	.351	2.07 ± 1.02	.004	2.56 ± 2.47	.080
PPQ	0.516 ± 2.45	1.09 ± 0.62	.950	2.22 ± 1.30	.010	2.93 ± 1.30	.000
sPPQ	0.86 ± 2.77	1.34 ± 0.36	.950	5.61 ± 7.07	.010	3.28 ± 1.75	.185
vFo	1.35 ± 0.45	2.20 ± 0.41	.996	18.05 ± 26.92	.016	6.15 ± 3.02	.675
Amplitude perturbation measures							
ShdB	0.27 ± 0.097	0.35 ± 0.18	.936	0.87 ± 0.13	.025	1.25 ± 0.80	.000
Shim	3.12 ± 1.18	3.95 ± 2.00	.961	9.77 ± 1.47	.030	10.99 ± 11.51	.000
APQ	2.47 ± 0.81	2.91 ± 1.37	.984	6.91 ± 1.32	.046	10.20 ± 6.55	.000
sAPQ	4.37 ± 1.35	4.24 ± 1.64	.999	7.89 ± 1.53	.085	11.01 ± 5.19	.000
vAm	12.00 ± 5.40	11.87 ± 2.70	.100	15.87 ± 1.99	.544	23.39 ± 7.15	.002
Noise related parameters							
NHR	0.15 ± 0.21	0.12 ± 0.03	.100	0.27 ± 0.20	.079	0.26 ± 0.15	.052
Voice break, voiceless segments and subharmonic measures							
DVB	0.00 ± 0.00	0.00 ± 0.00	.100	0.64 ± 1.43	1.00	0.19 ± 0.38	.939
DSH	0.00 ± 0.00	0.70 ± 1.56	.100	7.5 ± 6.50	.000	1.16 ± 2.01	.799
DUV	0.09 ± 0.32	0.00 ± 0.00	.100	15.83 ± 20.24	.404	27.74 ± 42.49	.030
NVB	0.00 ± 0.00	0.00 ± 0.00	.100	0.00 ± 0.00	1.00	0.50 ± 0.58	.002
NSH	0.00 ± 0.00	0.00 ± 0.00	.100	1.67 ± 2.89	.023	0.00 ± 0.00	1.00
NUV	0.77 ± 0.28	0.60 ± 1.34	.100	13.67 ± 13.61	.291	27.50 ± 32.26	.004
Aerodynamic changes parameters							
MPT	17.15 ± 4.58	12.00 ± 3.46	.127	9.33 ± 5.13	.044	10.00 ± 5.77	.038
Phonatory efficiency	118.20 ± 127.19	36.32 ± 47.80	.429	20.40 ± 10.00	.377	36.35 ± 10.60	.521
Phonatory resistance	51.26 ± 54.05	0.89 ± 0.36	.147	1.43 ± 0.89	.224	0.79 ± 0.67	.216

cordectomy especially type I may be viewed as phonosurgical procedure.[5] The inability of bilateral cordectomized patient to acquire significant better results, highlight again the impact of degree of surgical resection as well as bilateralism on voice quality.

The analysis and discussion of the data was first complicated by the inclusion of two extremely different surgical techniques not objectively studies in literature and second by the association of bilaterality to the degree of resection which was more extensive in cases subjected to bilateral laser cordectomy. Although in agreement to Remacle's findings who highlights that voice therapy is able to compensate for voice especially in absence of anterior synechia, and intact contralateral vocal fold,[5] our study did not confirm the role of voice therapy in improving voice quality because of small study sample. Bilateralism as well as extension of operation and subsequently the type of compensatory behavior should be carefully examined and considered in determination of postoperative voice outcome. Future biomechanical assessment of the laryngeal functions may add future insights to the interpretation of the results and direct the attention of both the surgeon and phoniatrician to the areas of weaknesses and strength in surgical rehabilitation techniques. The efficacy of surgical technique in constructing pseudoglottic for example should be considered and studied on biomechanical basis.

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