Acoustic and Aerodynamic Analysis of Tracheoesophageal Speech after Total Laryngectomy

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Abstract

Objectives/Hypothesis: The purposes of the study were to determine the acoustic and aerodynamic measurements of voice of the patients underwent primary tracheoesophageal voice prosthesis (TEP) after total laryngectomy (TL).

Patients and Methods: From May 2007 to July 2011, 16 male patients presented with advanced laryngeal tumor at Al Hussein University Hospital underwent TL and primary TEP participate in this study, no secondary TEP was done. All patients who underwent acoustic and aerodynamics study were at least 6 months of the postoperative period. Voice recording was carried out by using the Multi-Dimentional Voice Program, Kay Elemetrics corp. using the software option for Muti-Speech. The following acoustic measurement parameters were used in this study: Fundamental frequency, intensity, the Jitter and Shimmer. In addition, aerodynamics measures in the form of maximum phonation time (MPT). Computer analysis compared fundamental frequency, intensity, Jitter, and Shimmer with a male control group that had normal larynxes, and no complaints about voice. Statistics were done by computer using Instat-ANOVA.

Results: Among the TL/TEP speaker, average fundamental frequency was statistically significantly lower than normal. The mean of the average fundamental frequency 107.05 ± 49.968 SD with range between 71.448Hz and 226.24Hz. Intensity was lower than normal, but not statistically significant. The mean was 59.156 ± 5.209 SD with range between 47.59dB and 69.16dB. Jitter was high and statistically significant comparing to the normal. The mean of the jitter was 6.338 ± 5.481 SD with range between 0.5800 and 22.129. Shimmer was high and statistically significant comparing to the normal. The mean of the shimmer was 1.889 ± 0.9537 SD with range between 0.1770 and 3.484. MPT was lower and statistically significant when compared to the normal. The mean was 10.494 ± 3.887 SD with range between 5.130 seconds and 17.020 seconds.

Conclusion: In conclusion, TEP has improved speech quality after TL and it is now, the method of choice for many patients and physicians. Compared with other methods of communications, a higher number of patients achieve an acceptable voice, enabling them to communicate under virtually all social circumstances. Finally, this study will encourage the authors for future researches on acoustic analysis of different method of voice rehabilitations after treatment of laryngeal tumors and with other researches in different institutions.

Key Words: Acoustic aerodynamic analysis – Tracheoesophageal speech.

Introduction

SINCE the first total laryngectomy (TL) performed by Billroth in 1874, surgeon’s main concern was about sepsis and aspiration. By the end of the 19th century these problems reduced due to improved surgical techniques especially with the surgical tie-off and separation of the upper esophagus from the everted trachea, which lessened these life-threatening problems [1]. It is not until the mid of the 20th century, the survival rate of patients with laryngeal cancer improved and exceed 50%. Gradually, focus shifted from saving a life to enhancing its quality [2].

Total laryngectomy significantly alters the individual’s quality of life. Loss of voice after this operation has been the major concern [3]. Language expressed through speech is a fundamental characteristic of human communication. Its loss, therefore, severely disrupts interactions with others and results in significant psychological changes. Failure to adjust often leads to social withdrawal and decrease in the quality of life [4].

Voice restoration following total laryngectomy remains a challenging problem for head and neck surgeons and speech pathologists. It is, however, the key for laryngectomees to return to the productive life. Complete tumor ablation is the head and neck surgeon’s first treatment objective, but restoring fluent, intelligible speech to laryngectomees should have high priority [8].

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Currently, different methods for improving communication capabilities after total laryngectomy are currently available. These modalities consist of esophageal injection speech, various electrolaryngeal devices and tracheoesophageal puncture (TEP) with insertion of valve prosthesis. Patients unsuccessful in using one of these methods are left with hand and facial gesturing, mouthing words, or writing notes on paper as a mean of communication [6].

For many years, esophageal speech was considered the traditionally dominant approach of rehabilitation after TL. This method of communication was thought to be achievable by most of the patients, but this is, unfortunately, not true. Investigators studied the esophageal speech acquisition which showed that, about 75% of laryngectomees fail to acquire functional esophageal speech [7]. Additionally, it provides patients with a monotonous voice of decreased pitch and loudness, adequate only for communication in small groups and quiet settings. Therefore, when this method becomes feasible by the patient, the quality tends to be disappointing [8].

Electrolarynx was considered the second method of choice for patients who were unable to learn esophageal speech. A hand-held machine is placed in contact with the soft tissues of the neck to transmit vibrations to the floor of the mouth, and the patient uses the articulators to create speech [9]. Although electrolarynx has higher intensity level, the quality of voice is somewhat machinery and monotonous with limitation on inflection and emotion in sound production. In addition, the necessity to use a hand to operate & its dependence on batteries made it less favorable [10].

The third and most recently developed method is the TEP. In this method, a surgically one-way-valve voice prosthesis is surgically inserted. It provides a route whereby pulmonary air can be diverted from the trachea into the esophagus, while the patient closing the stoma. This creates sound by causing a portion of the mucosa to vibrate in the PE-segment [11].

TEP can be performed as an immediate or a delayed procedure. An immediate (primary), puncture is performed at the same time of TL. A delayed (secondary), puncture is performed 6 to 8 weeks or longer after surgery or postoperative radiation therapy (RT) [12].

Aim of the work:

The purposes of the study were to determine the acoustic and aerodynamic measurements of voice of the patients underwent primary TEP after TL.

Patients and Methods

From May 2007 to July 2011, 16 male patients presented with advanced laryngeal tumor at Al Hussein university hospital underwent TL (with unilateral or bilateral neck dissection) and primary TEP participate in this study. A standard technique of primary TEP fistula with insertion of prosthesis was done. In addition, all patients underwent pharyngeal myotomy. No secondary TEP was done in this study.

Fig. (1): Voice prosthesis in a patient underwent TL.

The method of TEP speech production and care of the prosthesis were taught to the patients by the surgeon and speech pathologist during routine follow-up visit in the ENT clinic. All patients in this study underwent postoperative RT. All patients who underwent acoustic and aerodynamics study were at least 6 months of the postoperative period. All patients were free from disease at the time of study. Patients were assessed at their routine outpatient clinic visit.

Voice recording was carried out by using the Mutli-Dimentional Voice Program (MDVP Model 5105 version 2.0, Kay Elemetrics corp.) using the software option for Muti-Speech. The acoustic signals were recorded for each patient while seated on examination chair in a quiet room.

TEP speaker were instructed to clear their throat then sustain a vowel /a/ for 3-4 second at typical habitual conservation for three times. The patients were guided to use their most comfortable way of stomal occlusion. A dynamic microphone was positioned at a constant mouth-to-microphone
distance of 10-15 cm. A 2-second midvowel segment was selected and analyzed. The average of the 3 attempts was taken. The following acoustic parameters were used in this study: Fundamental frequency, intensity, the jitter and shimmer.

Fundamental frequency correlative to the perceptual phenomenon of pitch. It represents the number of times the vocal folds (VFs) open and close per second i.e the vibratory rate of the vocal folds. During sustained phonation, men typically exhibit average fundamental frequencies between 100 and 150 Hz.

Intensity refers to the power of the tone produced at the VFs. Intensity relates to loudness as frequency relates to pitch. During sustained comfortable phonation, the intensity range is between 70 to 75 dB. Jitter % represents the relative period-to-period (very short term) variability in frequency. It is very sensitive to pitch variations occurring between consecutive pitches, while shimmer represents the relative period-to-period (very short term) variability of amplitude. They have been implicated as physical correlates of dysphonia.

In addition, aerodynamics measures in the form of maximum phonation time (MPT) was determined by asking the patient to sustain the vowel /α/ at their habitual pitch and loudness as long as possible for three times. MPT is defined as the best longest attempt in seconds. The time was recorded by the means of a stopwatch. MPT is a commonest test for evaluating the aerodynamic voice-pulmonary function. One would expect normal adult male subject to sustain /α/ vowel for about 17 to 34 seconds.

Computer analysis compared the acoustic and aerodynamic measures of the TEP patients with male control group (average age 51 years) that had normal larynxes, and no complaints about voice.

Statistics were done by computer using Instat-ANOVA. Software, a word processing, data base and statistics program. Data had a normal distribution to use Student’s t-test for non-related samples to compare numerical data in the study and the control groups. The significance level (p) was 0.10.

**Results**

The total number of patients underwent TL with primary TEP was 16. The mean age was 55 years (± 7.914) and range between 45 and 73 years. All patients in the study were males. All patients experienced RT.

Regarding voice analysis, average fundamental frequency was statistically significantly lower than normal. The mean of the average fundamental frequency 107.05 ± 49.968 SD with range between 71.448 Hz and 226.24 Hz among the TL/TEP speakers (Table 1).

**Table (1): The difference between TEP patient and normal as regard Average Fundamental Frequency.**

<table>
<thead>
<tr>
<th></th>
<th>(Mean±SD)</th>
<th>Range</th>
<th>t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEP</td>
<td>107.05±49.968</td>
<td>71.448-226.2410</td>
<td>t=0.165 8</td>
<td>0.04350</td>
</tr>
<tr>
<td>Control</td>
<td>123.93±8.131</td>
<td>73-169.28</td>
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</tbody>
</table>

Intensity was lower than normal, but not statistically significant. The mean was 59.156 ± 5.209 SD with range between 47.59 dB and 69.16 dB among the TL/TEP speakers (Table 2).

**Table (2): The difference between TEP patient and normal as regard Intensity.**

<table>
<thead>
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<th></th>
<th>(Mean±SD)</th>
<th>Range</th>
<th>t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEP</td>
<td>59.156±5.209</td>
<td>47.59-69.16</td>
<td>t=2.017 0.0546</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>55.241±2.440</td>
<td>50.43-58.57</td>
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</table>

Jitter was high and statistically significant comparing to the normal. The mean of the jitter was 6.338 ± 5.481 SD with range between 0.580 and 22.129 among the TEP speakers (Table 3).

**Table (3): The difference between TEP patient and normal as regard Jitter.**

<table>
<thead>
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<th></th>
<th>(Mean±SD)</th>
<th>Range</th>
<th>t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEP</td>
<td>6.338±5.481</td>
<td>0.580-22.129</td>
<td>t=2.648 0.0077</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>1.060±1.416</td>
<td>0.2370-2.451</td>
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</table>

Shimmer was high and statistically significant comparing to the normal. The mean of the shimmer was 1.889 ± 0.9537 SD with range between 0.1770 and 3.484 among the TEP speakers (Table 4).

**Table (4): The difference between TEP patient and normal as regard Shimmer.**

<table>
<thead>
<tr>
<th></th>
<th>(Mean±SD)</th>
<th>Range</th>
<th>t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEP</td>
<td>1.889±0.9537</td>
<td>0.1770-3.484</td>
<td>t=2.490 0.0108</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.7951±1.057</td>
<td>0.2090-3.383</td>
<td></td>
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</tr>
</tbody>
</table>

MPT was lower and statistically significant when compared to the normal. The mean was 10.494 ± 3.887 SD with range between 5.130 seconds and 17.020 seconds among the TEP speakers (Table 5).
Table (5): The difference between TEP patients and normal as regard MPT.

<table>
<thead>
<tr>
<th></th>
<th>(Mean±SD)</th>
<th>Range</th>
<th>t-test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEP</td>
<td>10.49±3.887</td>
<td>5.13-17.02</td>
<td>t=5.268</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Control</td>
<td>23.02±7.494</td>
<td>15.1-40.5</td>
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</table>

**Discussion**

Ablation of the laryngeal tumor is the surgeon’s first treatment objective, but restoring fluent, intelligible speech to the patient should have high priority [13]. Voice restoration following TL is the key for laryngectomees to return to the productive life. Voice rehabilitation after TL has shown considerable progress over the past three decades, mainly triggered by the development of voice prosthesis by Blom and Singer in 1980 [14].

Though, esophageal speech and electrolarynx are still used widely as a method of voice rehabilitation after total laryngectomy, studies indicate that only 40% of patients using an electrolarynx, and 33% of patients using esophageal speech report being satisfied with their quality of life [15].

TEP with subsequent placement of one-way valve voice prosthesis has improved speech quality and it is now, the method of choice for many patients and physicians. Compared with other methods of communications, a higher number of patients achieve an acceptable voice, enabling them to communicate under virtually all social circumstances. Success rates up to 90% makes prosthetic voice rehabilitation is the method of choice [16].

In this study, the fundamental acoustics parameters; fundamental frequency, intensity, perturbation percentage (jitter and shimmer) and maximum phonation time were measured. In the TEP patients, fundamental frequency was 107.05±49.968 SD with range between 71.448Hz and 226.24Hz, intensity was 59.15±5.209 SD with range between 45.59dB and 69.16dB, jitter was 6.33±5.481 SD with range between 0.5800 and 22.129, shimmer was 1.889±0.9537 SD with range between 0.1770 and 3.4840, and MPT was 10.49±3.887 SD with range between 5.130 seconds and 17.020 seconds.

In contrast to other published studies in TEP, acoustic and aerodynamics measures in this research are comparable. The variation in some parameters may be due to different surgical details among them.

Robbins et al. [17] measured selected acoustic features for different types of communications after total laryngectomy. They tested fifteen speakers who used TEP as their primary method of communications. They found that the fundamental frequency was 101 Hz±54.6, intensity was 79.4dB±2.1, and MPT was 12.2±5.2 seconds. In another study, Pindzola and Cain [18] measured the acoustic parameters in a comparative study of the esophageal, the TEP and the normal laryngeal voice. They found that, TEP speakers measures were significantly better than the esophageal speakers but less than the normal. Fundamental frequency was 107±33Hz and the MPT was 16±5 seconds. Van As et al. [19] found that, the fundamental frequency was 115.2±34.4Hz and the MPT was 13±4 seconds in 21 patients underwent standard laryngectomy with TEP.

In addition, when comparing TEP acoustic & aerodynamic analysis in this study with other methods of voice rehabilitation (esophageal & electrolarynx) in different published studies, authors found that, TEP speakers have superior results. The air reservoir available by the pulmonary supply in TEP patients allows for louder phonation, better intelligibility, higher speech rate, and more sustained phrasing of words in addition to better MPT.

**Conclusion:**

TEP has improved speech quality after TL and it is now, the method of choice for many patients and physicians. Compared with other methods of communications, a higher number of patients achieve an acceptable voice, enabling them to communicate under virtually all social circumstances. Finally, this study will encourage the authors for future researches on acoustic analysis of different method of voice rehabilitations after treatment of laryngeal tumors and with other researches in different institutions.

**References**


