THE ROLE OF VOICE ANALYSIS IN THE RECOVERY PROCESS OF CERTAIN OTO-RHINO-LARYNGOLOGICAL DISEASES

Dr Zoltán Fent

Consultant:
Prof. Dr. Mária Gósy DSc, university professor

Budapest
2010
1. Introduction

The most important means of human communication is speech. In recent years quality of life has become an even more important factor during individual oncological interventions, thus during the treatment of head-and-neck tumors, as well.

In Hungary the number of malignant head-and-neck tumors, including hypopharyngeal and laryngeal tumors has increased significantly. A portion of recognized tumors can only be treated with total laryngeal extirpation. Recently, with developing surgical techniques, the approach of functional preservation has come to the foreground: more and more patients undergo only partial laryngectomy, and these patients would have previously undergone total laryngeal extirpation.

We cannot be satisfied by curing the disease, and removing the tumor in itself: the quality of verbal communication crucially affects the patient’s quality of life as well as his/her readaptation to civil life. If this is not successful – considering the tight relationship between physical and mental processes – then frustration deteriorates the recovery and survival potential of the patient.

Facial nerve paresis – due to its obvious nature – severely damages interpersonal relations. Starting the adequate treatment as soon as possible depending on the etiology is extremely important with regards to recovery.
Objectives of the dissertation:

1) To study the effect of surgical interventions performed as the treatment for malignant laryngeal tumors on the quality of voice and quality of life,

2) To establish the relationship between the self-assessment of speech of partial- and total laryngeal extirpated patients and the assessment of the listeners

3) To study the significant alterations in the quality of voice after supracrlicoid horizontal laryngeal surgical intervention

4) To study the limitations of voice analysis in patients who underwent laryngeal operations; can the self-assessment of patients’ speech based on the quality of life test be matched with the value obtained during their voice analysis?

5) Will articulation change during peripheral facial nerve paresis?

6) Is there any relationship between the temporal changes of paralyzed facial nerve excitability, and the change in results obtained during voice analysis?

7) Which parameter(s) tested during voice analysis of which vowels are most suitable to monitor the recovery process of facial nerve paresis?
2. Structure of the dissertation

The dissertation consists of 14 chapters.
Chapter 1, the introduction describes the subject and its actuality, as well as the general aim of the research.
Chapter 2 is an anatomical overview. It outlines the knowledge that is indispensable to interpret the research summarized in the dissertation. The first subchapter details the structure of organs involved in voice formation, while the second subchapter discusses the facial nerve.
Chapter 3 summarizes the physiology of voice formation, as well as the acoustic and phonetic characteristics of human voice and speech.
The first subchapter of Chapter 4 introduces everyday and experimental testing methods of organs of speech. The second subchapter discusses the testing methods of the facial nerve and the reasons of peripheral facial nerve paresis, as well as the most frequent associated clinical pictures.
Chapter 5 overviews laryngeal- and hypopharyngeal surgical treatment options. Consequences of total laryngectomy and the method of voice rehabilitation are detailed. It also outlines laryngeal operations performed as part of my research later presented in the dissertation.
Chapter 6 provides a literature review of the effect of partial laryngeal operations on voice formation and speech.
Chapter 7 examines parameters influencing quality of life in patients who underwent surgical intervention due to a laryngeal or pharyngeal tumor.
Chapter 8 describes comparative testing of the speech of patients who underwent a partial laryngeal operation. It compares and discusses the opinion of the listeners of the perception test and the patients' self-assessment grouped according to the type of surgical intervention.
Chapter 9 demonstrates the acoustic analysis of the speech sound developed after supracricoid horizontal laryngeal resection. It investigates the reasons
of significantly different speech production of the two types of reconstructional options after surgery.

Chapter 10 provides a comparison of the speech of patients who underwent laryngeal operations both on objective and subjective bases. It also elucidates the potentials and limitations of voice analysis.

Chapter 11 details the perception tests of patients after total laryngectomy. The self-assessment of patients communicating with esophageal speech and of those using electrolarynx is compared with the impression of the listeners.

Chapter 12 details the monitoring of recovery processes of facial pareses using voice analysis. Results obtained during voice analysis are compared with results of the widely used NET test.

Chapter 13 summarizes the results.

Chapter 14 lists the references used.
3. Materials, methods, research subjects

In the dissertation – first in Hungary – we applied the QLQ-C30 quality of life test of the European Organization for Research on Treatment of Cancer (EORTC), as well as the head-and-neck-tumor specific H&N35 quality of life test.

Statistical analyses were performed with SPSS version 13.0 and 15.0 software.

Voice analysis was performed using Praat software version 4.3, 4.4, and 4.5.

Research subjects were selected from patients treated at the Department of Oto-Rhino-Laryngology and Head-and Neck Surgery.

4. Testing quality of life in patients who underwent a laryngeal operation

The study included 54 patients who had undergone hemilaryngectomy, supraglottic horizontal-, supracricoid horizontal, or supracricoid lateral laryngeal resection or total laryngectomy, with or without voice-prosthesis implantation.

Our objective was to establish: which parameters influence mostly general quality of life and subjective health status in the period after the surgical intervention.

Statistical analysis of data was performed using discriminant analysis („canonical variate analysis“ = CVA). Results are represented on a biplot that graphically illustrates the relationship of the variables and the axis (Figure 1).

General health- and quality of life values correlate with the extent of intervention. The subjective health state and quality of life of subjects eligible for voice-prosthesis implantation is significantly higher than that of those living without a voice-prosthesis.

After surgery, on the long run communication skills significantly influence the patient’s quality of life. Recidivation- and metastasis free survival can be evaluated only together with quality of life, this latter can only be
improved by bringing organ- and function preserving oncological treatment methods into the foreground.

5. Comparative test of speech intelligibility of patients who underwent partial laryngeal operation using perception test

During this study we analyzed the relationship between the listeners’ opinion and self-assessment indexes for speech of quality of life tests according to groups of the type of surgery performed. Individuals (participants) between the age of 18 and 25 with normal hearing listened to the voice recording containing spontaneous speech of patients. Afterwards they evaluated the quality and the intelligibility of the speech of patients by answering the questions of the perception test. From among the standardized quality of life tests completed by the patients (EORTC QLQ-C30, Head and Neck 35) we highlighted the responses that were given to the communication skills.

The results are shown in Figure 2.

![Figure 2](image-url)
The comparisons reveal that qualification by patients and by participants do not correlate for each type of surgery; one possible explanation is different expectation by patients with regards to post-surgery quality of voice. Self-assessment of speech function is influenced by the type of laryngeal operation performed. The larger the extent of residual defect in the larynx is, the worse the value of their evaluation is.

The results obtained demonstrate that patients who underwent partial laryngeal operation communicate well in everyday life, and this is not only based on self-assessment, but also on the opinion of their environment.

6. “Zönge” (tone produced by the vibration of the vocal cords) voice formation potentials after supracricoid horizontal laryngeal resection

Significant differences can be observed in the quality of voice of patients who underwent supracricoid horizontal resection. Some patients are only able to form a weak, whispering-type voice, while others produce a voice of satisfactory volume, but hoarse. Based on our investigations performed on the group of 11 patients, differences of the place for forming the "zönge" voice (tone produced by the vibration of the vocal cords) constitute the background of voice quality differences. If the epiglottis can be preserved (CHEP), the place for forming the “zönge” voice will be between the edge of the epiglottis and the posterior pharyngeal wall (Figure 3). If the arytenoid region is preserved, the place of “zönge” voice formation will be between the arytenoid region and the epiglottis (Figure 4). After a reconstruction with epiglottis removal (CHP), in certain cases no “zönge” voice is formed at all; air flows unarrested through the glottis (Figure 5). During their speech these patients try to use the “friction” of the air passing through the strictures of the hypopharynx as primary voice. In other cases of reconstruction with epiglottis removal the place for “zönge” voice formation
is the substitute vocal cord formed between the preserved arytenoid region and the root of the tongue.

Figure 3. The place of “zönge” voice formation is between the epiglottis and the posterior pharyngeal wall

Figure 4. The place of “zönge” voice formation is between the epiglottis and the arytenoid region

Figure 5. The place for forming “zönge” voice is missing
During the acoustic analysis of patients’ voice recordings, we established the basic frequency, and during the examination of a sustained vowel we measured the extent of frequency- an amplitude fluctuation, as well as the signal/noise ratio. By comparing the results obtained with those obtained for a voice formed with a normal larynx, we established that the harsh tone of the voice formed with the epiglottis is explained by a higher than normal fluctuation of frequency- and amplitude, as well as by the deterioration of the signal/noise ratio.

7. Relationships of objective and subjective assessments of speech in patients who underwent a laryngeal operation

In our study we examined the acoustic parameters of the speech of 95 patients operated for laryngeal- or hypopharyngeal tumors, and compared them with answers related to quality of life of EORTC questionnaires. 10 adult males with normal larynx served as the control group.

We aimed to establish in patients who underwent various types of partial laryngectomy or total laryngectomy due to a malignant tumor and rehabilitated using various methods, to what extent can communication abilities experienced by the patients be objectivized with acoustic parameters measured during their voice analysis.

From among the responses given to the questions we pay special attention to those that were provided related to general health state, quality of life, as well as speech, social contacts and social functions.

From among the acoustic parameters we analyzed the phonation time, speech rate, articulation speed, fundamental frequency, number of detectable formants, the rate of frequency and intensity fluctuation, as well as the signal/noise ratio. The results are shown in Table 1 and 2.
There is positive correlation between the subjective self-assessment of post-surgery voice and speech by patients and the general status of health and quality of life.

After surgery, on the long run communication skills significantly influence the patient’s quality of life.

The quality of speech and communication abilities of patients who underwent laryngeal operations can be objectivized by measuring - from among the studied acoustic parameters - the jitter, the shimmer, the maximal phonation time and signal/noise ratio, thus the successfulness of the various operational techniques and voice rehabilitation methods are more easily compared (Figure 6).
Figure 6. The relationship of jitter and shimmer to social functions and quality of life

The rate of frequency and amplitude fluctuations is inversely proportional to the subjective quality of life: QOL/jitter - \([r= -0.68, p<0.05]\] QOL/shimmer - \([r= -0.76, p<0.05]\]

("általános eg" = general health, "szociális funkciók" = social functions)

8. Studying esophageal speech and fundamental frequency formed with an electric artificial larynx after total laryngectomy

During the perception test performed with the inclusion of 11 patients we compare the impressions of the listeners of speech quality and intelligibility with the self-assessment of speech provided by total laryngeal extirpated patients. Objectives:

To establish if there is any relationship between the assessment of the speaker and that of the conversation partner. Are there any differences in this respect between those using an electric larynx and those with esophageal speech?

Based on the self-assessment of speakers, those using an electric larynx are more satisfied with their speech and communication efficiency than those applying esophageal speech. However, according to the assessment provided by the listeners, esophageal speech proved to be significantly better both with respect to speech quality and speech intelligibility. The results show
that esophageal speech allows for a more successful communication, thus for a more efficient re-adaptation to society.

9. Monitoring of recovery processes of facial pareses using voice analysis

In our study we compared NET (nerve excitability testing) test results of patients suffering from peripheral facial nerve paresis with the results of their voice analysis, by which we monitor their voice formation.

Our objective was to establish:

- Will articulation change during peripheral facial nerve paresis?
- Is there any relationship between the results of the NET test (excitability of the paralyzed facial nerve) and the results of voice analysis?
- Which parameter(s) tested during voice analysis of which vowels are most suitable to monitor the recovery process of facial nerve paresis?
- In case of the 3 examined branches (temporal, zygomatic, and marginal mandibular) which, to what extent and in case of which vowels show a significant relationship with the changes of NET values?

We asked the 30 study participant patients to repeat 1-2-syllable, vocabulary form words containing mostly front-formed, labial articulation vowels and sentences after hearing them read out. We randomly selected 3-3 identical vowel from the voice recorded during patient visits. We analyzed the 8 tested vowels from the voice record, taking care to analyze the vowel coming from the same word or sentence when the specific patient performs his/her next visit.
We compared the results of the voice analysis of the voice record (F0, jitter, shimmer, signal/noise ratio) with the NET results.

In order to show correlation when comparing the mean of the NET values and of acoustic measurements we calculated Pearson’s correlation coefficient. The results are shown in Table 3.
Table 3. Correlations of front formed, rounded vowels. A yellow field indicates which acoustic parameter change of the specific vowel correlates with NET value changes measured on the defined facial nerve branches.
Based on the results we can establish that during facial nerve paresis articulation changes can be observed in each case.

From among the tested parameters of voice analysis, NET test results show correlation with fundamental frequency (F0), jitter, shimmer and the signal/noise ratio.

From the three facial nerve branches tested by us in the majority of cases we observed a correlation with regards to articulation change on the zygomatic branch and on the marginal mandibular branch.

We could reveal most correlations in case of these 2 branches and for the front formed long vowels.

For each tested vowel F0 change correlates with NET values in case of the zygomatic branch and marginal branch.
10. Results and Conclusions

1. In Hungary we were the first to perform a comprehensive quality of life testing according to international standards in 2 periods on a total number of 149 patients who underwent total- and partial laryngectomy by using the QLQ-C30 quality of life test of the European Organization for Research on Treatment of Cancer (EORTC), as well as the head-and-neck-tumor specific H&N35 quality of life test. We established that on the long run communication skills are decisive with regards to patients’ quality of life.

2. By using the perception test we established that the larger the extent of the defect remaining after the surgery in the larynx, the worse is the listeners’ assessment for speech quality and speech intelligibility. Patients who underwent partial laryngeal operation communicate well in everyday life, and this is not only based on self-assessment, but also on the opinion of their environment.

3. By testing the reasons of significant voice quality alterations observed after supracricoid horizontal laryngeal operations, we revealed potential ways of primary voice formation and their acoustic consequences.

4. We established that after total- or partial laryngectomy, there is a positive correlation between the subjective assessment of post-surgery voice and speech by patients and general status of health, and quality of life. The quality of speech and communication abilities of patients who underwent laryngeal operations can be objectivized by measuring - from among the acoustic parameters - the jitter, the
shimmer, the maximal phonation time and signal/noise ratio, thus the successfulness of the various operational techniques and voice rehabilitation methods are more easily compared.

5. Even internationally we were the first to test the effect of facial nerve paresis on articulation using the method of voice analysis. From among the tested parameters of voice analysis, NET test results show correlation with fundamental frequency (F0), jitter, shimmer and the signal/noise ratio. We could reveal most correlations in case of the front formed, long vowels.

6. Based on the results of this research the effect of paresis severity on articulation would worth to be investigated further with a modified set of words. Based on the results of these studies, voice analysis could be used in a new, practical way in the future.
Presentations related to the dissertation

Speech after total laryngectomy: the oesophageal and voice prosthesis sound
Fent Z., Kiefer G., Répássy G.
4th European Congress of Oto-Rhino-Laryngology Head and Neck Surgery

Tapasztalataink a percutan endoscopos gastrostoma alkalmazásával
előrehaladott fej-nyaki tumoros betegeken
Lőrincz T., Fent Z., Szirmai Á., Répássy G.

Az életminőséget meghatározó paraméterek garat és gégerákos betegeknél
Fent Z., Kiefer G., Jósa V., Répássy G.

A supracricoid horisontalis gégeresectio utáni beszédhang akusztikai
analízise
Kiefer G., Fent Z., Répássy G.:  

Supracricoid lateralis gégeresectio után képzett hang akusztikai analízise
Kiefer Gábor dr., Fent Zoltán dr., Bajnóczyné Szucsák Klára, Répássy Gábor
dr.
MFFLT és a MAGYE Kongresszusa, 2004. június 24-26., Pécs

A hangrehabilitáció eredményeinek összehasonlító fonetikai vizsgálata
Kiefer G., Fent Z.,Gósy M.
MTA, Budapest

Factors Defining Quality of Life in Patients with Pharyngeal and Laryngeal
Cancer (poster)
Fent, Zoltan; Kiefer, Gabor; Josa, Valeria; Repassy, Gabor;
5th European Congress of Oto-Rhino-Laryngology Head and Neck Surgery,
Comparative Acoustic Analysis of the Voice Rehabilitation After Partial and Total Laryngectomy
Kiefer, Gabor; Fent, Zoltan; Repassy, Gabor;

A beszéd objektív és szubjektív minősítésének összefüggései gégeműtötteknél
Fent Zoltán – Kiefer Gábor – Gósy Mária
XV. Magyar Alkalmazott Nyelvészeti Konferencia

Részleges- és teljes gégeeltávolításon átesett betegek beszédakusztikai paraméterei, szubjektív beszédmínősége
Fent Zoltán – Kiefer Gábor – Gósy Mária
MFFLT és a MAGYE Kongresszusa, 2005. június 16-18., Kőszeg

A gége betegségei és a zöngeképzés
Fent Zoltán
PhD kurzus előadás, 2005. november 17., ELTE BTK Fonetika Tanszék

Részleges gégeműtétésen átesett betegek nyelési funkciója
Fent Zoltán dr, Bajnócziné Szucsák Klára, Tóth Krisztina dr., Szabó Balázs dr., Répássy Gábor dr.
MFFLT és a MAGYE Kongresszusa, 2006. június 22-24., Hódmezővásárhely

Részleges gégeműtétésen átesett betegek nyelés rehabilitációja
Bajnócziné Szucsák Klára, Fent Zoltán dr., Halmos György dr., Répássy Gábor dr.
MFFLT és a MAGYE Kongresszusa, 2006. június 22-24., Hódmezővásárhely

Eltérő fonációúj beszédmódok percepciós vizsgálata Markó Alexandra,
Gráci Tekla Etelka, Fent Zoltán dr.
MFFLT és a MAGYE Kongresszusa, 2006. június 22-24., Hódmezővásárhely

Supracricoid horisontális gégeresectio 1997 és 2006 között. Retrospektív elemzés
Szabó B., Fent Z., Halmos Gy., Kiefer G., Tóth K., Répássy G.
szeptember 6-9., Debrecen

Parciális gégeműtéték rövid- és hosszútávú eredményeinek értékelése
Tóth K., Halmos Gy., Fent Z., Szabó B., Bódis F., Répássy G.
szeptember 6-9., Debrecen
Parciális gégmentéten átesett betegek életminőségének vizsgálata
Halmos Gy., Tóth K., Fent Z., Szabó B., Bajor B., Répássy G.
szeptember 6-9., Debrecen

Gége- és hypopharynxotumoros betegek életminőségének összevetése
beszédakusztikai paramétereivel
Fent Z., Szabó B., Tóth K., Halmos Gy., Kiefer G., Répássy G.
szeptember 6-9., Debrecen

Image guidance offers additional benefits in the endoscopic solution of
extended cranio-facial malformations. A case report
Andor Hirschberg, Zoltán Fent, Károly Hrabák, Ödön Rezek, Ron von Jako,
Gábor Répássy
International Journal of Pediatric Otorhinolaryngology Extra Volume 1,
Issue 3, September 2006, Pages 181-184

Különleges zöngeképzési módok hatása az észlelésre
Markó Alexandra PhD, Gráczi Tekla Etelka, dr. Fent Zoltán
Magyar Tudomány 167. évforduló 2007/3. szám

A hangképzésben részt vevő szervek anatómiája
Fent Z.
június 21-23., Eger

A klinikánkon 2004-ben bevezetett, komplex foniátriai vizsgálati protokoll
alkalmazásával szerzett tapasztalataink
Kiefer G., Fent Z.
június 21-23., Eger

Részleges gégmentéten átesett betegek beszédének összehasonlító
vizsgálata percepciós teszt segítségével
Fent Z., Markó A., Gráczi T.E.
június 21-23., Eger

Beszédéslelési és beszédmegértési zavarok az anyanyelv-elsajátításban
Szerk.: Gósy Mária. Fent Z. A hallószerv, a hallás folyamata, zavarok
Az arcidegbénulások gyógyulási folyamatának monitorozása hanganalízis segítségével
Fent Z., Bencsik B., Répássy G.

Az arcidegbénulások gyógyulási folyamatának monitorozása hanganalízis segítségével – esetismertetés
Bencsik B., Fent Z., Szirmai Á.

Reziduális epipharynx tumor endoszkópos eltávolítása és gamma terápiája
Fent Z., Szabó B., Fedorcsák I., Nagy R., Noszek L., Répássy G.

Az arcidegbénulások gyógyulási folyamatának monitorozása hanganalízis segítségével – újabb eredmények
Bódis F., Fent Z., Bencsik B., Répássy G.

A supracricoid horisontalis gégeresectio utáni beszédhang akusztikai analízise
Kiefer Gábor dr., Fent Zoltán dr., Répássy Gábor dr.
Fül-orr-gégegyógyászat, megjelenés alatt

Az életminőséget meghatározó paraméterek garat- és gégerákos betegeknél
Fent Zoltán dr., Kiefer Gábor dr., Jósa Valéria, Répássy Gábor dr.
Magyar Onkológia, megjelenés alatt