Department of Otorhinolaryngology – Head and Neck Surgery

Division of Phoniatrics and Pediatric Audiology

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Research Focus

- Kinesthetic and auditory feedback during phonation and articulation
- Modeling of tracheoesophageal voice
- Development of vocal fold transplants
- Phonovibrography – objective analysis of vocal fold vibrations
- Differentiated objective analysis of the speech quality of chronically hoarse patients to enhance evidence-based diagnostics
- Fluid mechanical basis of the human voice

Structure of the Division

Phoniatrics and pediatric audiology is a medical field which addresses diseases and disorders of voice, speech, language, hearing, and swallowing. Research deals basically with communication disorders on the perception (hearing research) and production side (speech and voice research). The principle contents of the research projects within the Division of Phoniatrics and Pediatric Audiology connect the medical field with applied natural sciences and technology. 21 employees in all work at the Division of Phoniatrics and Pediatric Audiology, four of them are financed via third-party funds.

Research

Kinesthetic and auditory feedback during phonation and articulation

The precision of the human speech signal is controlled by parallel working feedback processes while speaking. The feedback mechanisms are developed during language acquisition and can be divided into kinesthetic and auditory control. The feedback mechanisms can be affected by voice and speech disorders in different ways.
This project investigates the feedback mechanisms of phonation and articulation of healthy test persons and compares their performance with patients suffering from voice (hyper-, hypotension dysphonia; MTD) and speech disorders (Apraxia of Speech; AOS). The synchronous data acquisition (visual, acoustical, and EEG) enables for the first time the analysis of the connection between kinesthetic and auditory feedback processes. Current methods of electrophysiology and quantitative endoscopy are used simultaneously. The goal of the study is a first understanding of the cooperating auditory and kinesthetic feedback control.

Modeling of tracheoesophageal voice

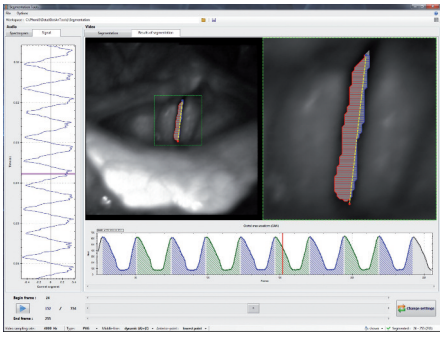
After laryngectomy, the loss of natural voice is the most prominent functional defect. It can be rehabilitated best by means of shunt valves. So far, there is no consensus on how to evaluate tracheoesophageal voice.
In a study funded by the German Cancer Aid, we objectively analyze the dynamics and the resulting acoustical signal of the remaining pharyngoesophageal segment after total laryngectomy. The goal is to find correlations between dynamics as well as tissue structures and the quality of the resulting acoustic signal. High-speed recordings in combination with a newly developed laser grid projection system are applied. This combination allows a quantitative registration of occurring dynamics. The dynamics are adopted by numerical biomechanical models. The resulting parameters, like damping and swinging masses, are further analyzed and interpreted.

Development of vocal fold transplants

Partly or full excision of the larynx results in the loss of voice production. Additionally to the cancer, the patients then have to deal with a very reduced ability to communicate. The goal of this project, funded by the German Cancer Aid, is to reconstruct new vocal fold tissue by means of nano-technologic approaches which can be implanted after surgery. This project is jointly executed with Prof. Dr. C. Alexiou (professorship for Nanomedicine, Department of Otorhinolaryngology).

Phonovibrography – objective analysis of vocal fold vibrations

The causes of hoarseness are not yet completely understood. The presumed irregularities of vocal fold oscillation cannot be proven with the conventional investigation instrument (stroboscopy) as this is only designed for periodic events. Thanks to funding of the DFG, a novel approach of phonovibrography could be developed which enables a visualization and analysis of vocal fold dynamics. In this approach, digital high-speed recordings of vocal fold vibrations, captured at a frame rate of 4000 Hz, are analyzed. For an objective analysis, a specialized image segmentation algorithm was developed which extracts the vibrating vocal fold edges from the high-speed recordings. The results of the procedure were extensively evaluated in a clinical trial. To visualize the relevant vibration information within a single image, the so-called phonovibrogram (PVG) was developed. A PVG image contains the entire vocal fold oscillation pattern and enables a novel classification of vocal fold vibrations. First studies show the robustness as well as the reliability of this new approach. For further quantification, a laser-grid projection device was developed which enables a three-dimensional quantification of the image data in the future. Thus, absolute measures of vocal fold elongation and velocities can be performed.
Within this project, we further developed an application software (Glottis Analysis Tools, GAT). The software is thought to be applicable in the clinical environment and routine in the future. In this research area, we closely collaborate with respected international colleagues who already apply and also review the software regarding the clinical benefit and applicability.



Screenshot of the developed software. The vocal folds (middle) to be segmented and a close-up of this picture (right) is given. On the left, the corresponding acoustical signal, on the bottom, the segmented glottal area is given.

Differentiated objective analysis of the speech quality of chronically hoarse patients to enhance evidence-based diagnostics

For differentiated diagnostics of functioning and evaluation of distorted voice and speech production, there are currently no validated objective approaches. Voice and speech disorders are usually assessed by perceptive evaluations with only restricted reliability for clinical or scientific use.

Perceptual evaluations are very time consuming and of limited suitability in clinical routine. For a differentiated, objective analysis, automatic methods are developed which take this into account. Subjective clinical evaluation criteria are described by objectively computed parameters. The involved patient groups include patients with voice disorders, e.g. chronic hoarseness, partial and total laryngectomy, and patients with articulation disorders, e.g. children with cleft lip and palate and patients with oral squamous cell carcinoma.

The automatic methods analyzed voice parameters as well as speech aspects with a strong focus on a detailed (phoneme) analysis. Thus, the communication problem is not described as one single unit, but phoneme classes have been identified which are specifically affected by the distortion.

Systems for a detailed phoneme analysis in children with cleft lip and palate and patients with oral squamous cell carcinoma were also established. These systems are based on automatic speech processing techniques, prosodic analysis, phonemic and phonological features. Additionally, the current topic is the quantification of hoarseness which will also include speech-related parameters for the first time. The objective measurement of nasality without complex and expensive equipment is also part of the research project. In this way, an objective clinical evaluation is created.

The automatic analysis is the basis for future telemedical applications for the control of the progress of voice and speech therapy. Furthermore, this analysis will serve as objective addition to the established subjective voice and speech evaluation in clinical practice. The approach is another important step towards evidence-based diagnostics in phoniatrics.

This project is jointly executed with the Pattern Recognition Lab (Prof. Dr. E. Nöth, Faculty of Engineering). The project is supported by the Else Kröner-Fresenius Stiftung.

Fluid mechanical basis of the human voice

More detailed information is given in the separate report of FOR 894, supported by DFG.

Teaching

The Division of Phoniatrics and Pediatric Audiology is dedicated to a first-class academic teaching which is of the same value as patient care and scientific research. The offer of lectures follows the clinical focus of the area. Phoniatrics and pediatric audiology are taught during both, the pre-clinical and clinical phase. Complementarily, practical trainings on voice, swallowing, speech, and hearing impairments are given.

The training of speech therapists takes place at the Institute of Speech Therapy (B.Sc. Logopedics) within the Faculty of Medicine.

We also give lectures for the degree program "Medical Engineering" where we teach the students how to transfer engineering knowledge towards clinical questions (Computational Medicine I).

Selected Publications

Bartke B, Haderlein T, Döllinger M, Nöth E, Graf S, Eysholdt U, Ziethe A. Perzeptive und maschinelle Stimm- und Sprechanalyse bei chronischer Laryngitis und T1-Stimmlippenkarzinom. HNO 2013, 61(8): 672-7

Echternach M, Döllinger M, Sundberg J, Traser L, Richter B. Vocal fold vibration at high soprano fundamental frequencies. J Acoust Soc Am 2013, 133(2): EL82-EL87

Unger J, Meyer T, Herbst CT, Fitch WTS, Döllinger M, Lohscheller J. Phonovibrographic wavegrams: Visualizing vocal fold kinematics. J Acoust Soc Am 2013, 133(2): 1055-64

Patel R, Dubrovskiy D, Döllinger M. Characterizing vibratory kinematics in children and adults with high-speed digital imaging. J Speech Lang Hear R 2014, 57(2): 674-86

Schulz A, Bocklet T, Eysholdt U, Bohr C, Döllinger M, Ziethe A. Validierung einer automatischen Analyse der Sprechproben von Kindern mit isolierter Gaumenspalte. HNO 2014, 62(7): 525-9

Bohr C, Kräck A, Dubrovskiy D, Eysholdt U, Svec JG, Psychogios G, Ziethe A, Döllinger M. Spatiotemporal Analysis of High-Speed Videolaryngoscopic Imaging of Organic Pathologies in Males. J Speech Lang Hear R 2014, 57(4): 1148-61

International Cooperations

Prof. J.G. Švec, Ph.D., C. Herbst, Ph.D., Palacký University, Olomouc: Czech Republic

Prof. Y.J. Moon, Ph.D., Korea University, Seoul: South Korea

Prof. R.E. Hillman, Ph.D., MD, D. Mehta, Ph.D., Massachusetts General Hospital, Boston: USA

Prof. D.A. Berry, Ph.D., University of California, Los Angeles: USA

Prof. S.L. Thomson, Ph.D., Brigham Young University, Idaho: USA

Prof. M. Kunduk, Ph.D., Louisiana State University, Baton Rouge: USA

Prof. R. Patel, Ph.D., Indiana University, Bloomington: USA