INTRAGLOTTAL CONTACT PRESSURES IN HUMAN VOICE PRODUCTION

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ABSTRACT

Some fundamental questions concerning voice production remain unanswered despite numerous research approaches in various fields of voice science. It is widely believed that high intraglottal pressures may cause organic voice disorders – like vocal fold nodules or contact granulomas. This hypothesis seems reasonable but is difficult to prove given the challenges of pressure measurement and of establishing a causative link to disease.

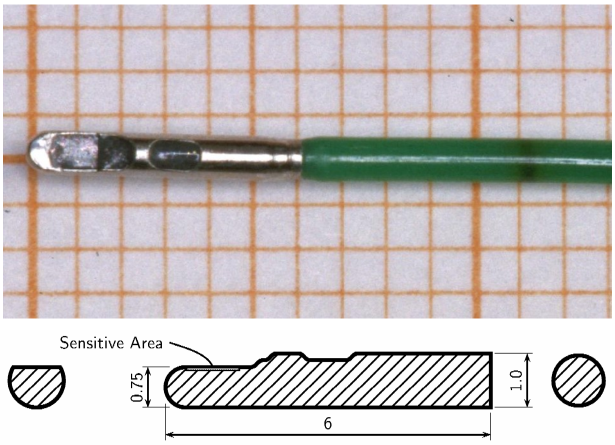
In this study we present a method for intraglottal contact pressure measurement in humans with a specially designed subminiature sensor. While implementing the measurement of the contact pressures, videolaryngoscopy is simultaneously used for online-monitoring. The new generation of subminiature sensors has now allowed us to make pressure measurements along the membranous vocal fold. We demonstrate contact pressure values for 10 healthy female and 10 healthy male subjects as well as for 10 patients with organic voice disorder. A video with endoscopic pictures illustrates the investigation procedure and data collection.

Keywords: intraglottal contact pressure, sensor, intermembranous position, interarytenoid position, videolaryngoscopy.

1. INTRODUCTION

During the nineties, the first endolaryngeal contact pressure measurements in humans have been successful [2,6]. In previous experiments endolaryngeal pressure measurements in the excised canine larynx [3] and in the excised bovine larynx [4] were described. Another valuable research approach for estimating endolaryngeal contact pressures is the use of mathematical modelling (5,1). In 2000 [7] a Japanese research team measured laryngeal closure pressure during phonation in humans. For the investigations they used a sensor with a diameter of 1 cm which enabled them to obtain contact pressures in the arytenoid region. In the present study the Hamburg research team uses a specially designed sensor with a pressure transducer area of 0.9 mm^2 (fig. 1). The technical enhancement with the outcome of a miniature sensor allows the measurement of contact pressures in the membranous part of the vocal folds.

Figure 1: Subminiature sensor



The questions of the study were: (1) What are the ranges of intermembranous pressures and of interarytenoid pressures in healthy subjects during phonation? (2) What are the magnitudes of pressures during phonatory and non-phonatory (effortful) tasks? (3) Is there a correlation between the pressure magnitude and fundamental frequency (F0) and sound pressure level (dB SPL)? (4) Are there gender differences for intraglottal contact pressures (according to different voice production in female and male subjects)? And, (5) Is there a difference of the pressure range of healthy subjects compared to subjects with organic pathologies (vocal fold nodules, vocal fold polyps and contact granulomas)?

2. METHODS

2.1. Subjects

We investigated on intraglottal contact pressures in 10 healthy adult males aged 24.2 to 32.0 years, 10 healthy females aged 19.6 to 30.8, 5 male patients with organic voice disorder aged 21.5 to 74.8, and 5 female patients with organic voice disorder aged 20.8 to 37.0. The healthy subjects were chosen by means of a two-part screening. First, the anatomical structures and proportions of the oral cavity and the larynx were scrutinized, an important criteria was how well the larynx was accessible for indirect sensor positioning. Crucial for the first part of the screening was the degree of gag reflex tested with a spatula. Only subjects with a minor gag reflex were chosen for the second part. The voice was examined perceptually and laryngostroboscopically. Then the speech therapist trained with the subjects all phonatory and non-phonatory tasks (table 1) that followed during the sensor investigation. Only subjects who could fulfill the tasks on demand were accepted for the study.

Table 1: Phonatory and non-phonatory tasks

Phonatory tasks	
Pitch	habitual pitch low, middle, high pitches chest register / head register glissando up and down
Loudness	moderate (mezzoforte), loud (forte), soft (piano) crescendo und diminuendo
Phonation type	breathy versus pressed voice quality
Voice on- and offset	soft versus hard voice onset soft versus abrupt voice offset

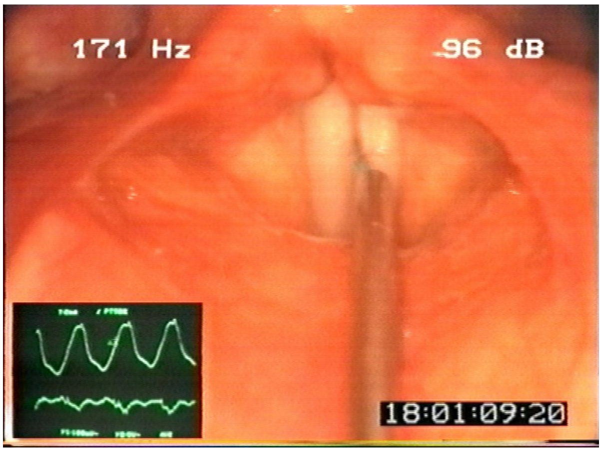
Non-phonatory tasks
throat clearing
coughing
fixation of thorax by effortful vocal fold closure
gagging

2.2. Examination

During the recording the subject sat upright on the examination chair slightly leaning forward, holding his tongue with a gauze square. The subject and examiner could rest their arms on a desk standing between them. For the videolaryngoscopy a rigid 90° endoscope was used. The examiner held the laryngoscope in his left hand while he guided the pressure sensor with his right hand. At the beginning of the recording a standard videotaping of the larynx was generated in respiration and phonation. After anesthetization of the larynx the sensor was placed at the targeted positions.

The methodology is based on the routine of phonosurgery under topical anesthesia online-monitored by videolaryngoscopy (fig. 2). The group of healthy subjects as well as the group of subjects with voice disorders were examined while accomplishing phonatory and non-phonatory tasks.

Figure 2: Video monitoring

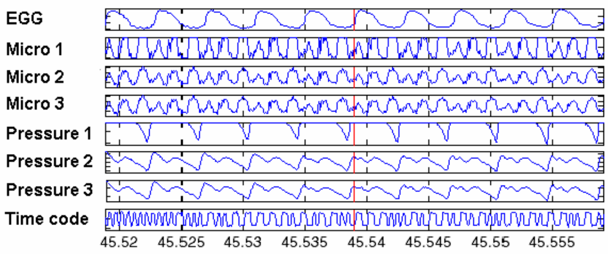


2.3. Data analysis

The digitized data were analyzed off-line. First, video sequences were selected based on proper sensor positions. When an intraglottal sensor position was found the corresponding signal sequences of pressure signal, microphone signal and EGG signal were identified by time code comparison. The corresponding signal sequences were evaluated with an individually adapted MatLab program (fig. 3). The microphone signal and the pressure signal were plotted in three channels with different amplifications, respectively.

For each analyzed signal sequence the pressure value and all further relevant parameters were represented in a data sheet. Simultaneously the voice quality as well as its correspondence with the required tasks was rated. Each data sheet represented one pressure measurement point and formed the basis for further analyses, for example to look for a correlation between pressure and frequency or pressure and sound pressure level, etc.

Figure 3: Data analysis (MatLab program): EGG signal, 3 microphone channels, 3 pressure channels, time code signal



3. RESULTS

- Intermembranous contact pressures in healthy subjects during phonation < 4 kPa
- Interarytenoid contact pressures are an order of magnitude higher
- Increasing sound pressures show a tendency of increasing contact pressures
- Increasing frequencies are not associated with increasing contact pressures
- Contact pressures for non-phonatory tasks were considerably greater
- No general gender differences for intraglottal contact pressures
- Higher values only in male patients with contact granulomas compared to healthy subjects

4. CONCLUSION

Intraglottal contact pressure measurements with simultaneous online recording of fundamental frequency and sound pressure level as well as videolaryngoscopic imaging provides a powerful examination setup to research the biomechanics of voice production. The subminiature sensor we used allowed us to collect contact pressure not only in interarytenoid but also in intermembranous sensor positions. The pressure values we measured in healthy subjects during voice production in intermembranous positions ranged below 4 kPa and match very well with the values estimated with the help of mathematical modelling.

5. REFERENCES

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