Voice Quality and Dysphagia:
Analysis of Perceptual, Acoustic, Electroglottographic Measurements and Videofluoroscopy
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1. Introduction

• swallowing and phonation represent two different biological functions

• they are interrelated by their shared anatomical structures

→ glottal behavior during phonation may deliver information about the swallowing process

→ connection of phonetic measurements of voice quality and diagnostic aspects of dysphagia is of special interest
2. Anatomy, Physiology and Pathophysiology of swallowing and phonation

Two functions of the vocal tract:

- respiration
- deglutition

And one uniquely human function:

- speech
A. Anatomy of the Pharynx

Fig. 1: Midline schematic of the pharynx, larynx and mouth
by Bosma, J.F. et al. (1986)
B. Physiology of Swallowing

- complex neuromuscular function for propelling saliva, liquids and food safely and efficiently from the mouth to the stomach with simultaneous protection of the lower airways by a firm laryngeal and glottal closure
- surprisingly frequent action: about once a minute
- a variety of sensory stimuli are present
The swallowing act can be divided into four main phases:

→ the oral preparatory phase
→ the oral phase
→ the pharyngeal phase
→ the esophageal phase
Fig. 2: (a) oral preparatory phase, (b) end of oral phase, (c) pharyngeal phase, (d) pharyngeal phase, (e) late pharyngeal phase, (f) esophageal phase

by Wuttge-Hannig et al. (1991)
Disturbance of Pharyngeal Phase:

- disturbance of two closing mechanisms: larynx and nasopharynx
- disturbance of opening mechanism of the upper esophageal sphincter
- intra- or postdeglutitive laryngeal penetration or aspiration
- retention of food in the pharynx
Assessment of Swallowing Disorders:

- **bedside or clinical evaluation** including history of patient’s swallowing disorder, evaluation of oral, pharyngeal and laryngeal anatomy, sensory and motor function, behavioral, language and cognitive assessment, trial feeding

- **videofluoroscopy**: radiographic examination with a variety of food types
C. Physiology of Phonation

• vocal folds are immediately relevant parts of the larynx for phonation
• vocal folds are attached at the front of the larynx to the thyroid cartilage and at the back to the arytenoid cartilage
• arytenoid cartilage can be made to rotate in a swivelling movement and to slide apart along the thyroid cartilage
• both actions open a three-dimensional triangular space between the inner edge of the vocal folds: the glottis
Fig. 4: Action and location of the laryngeal muscles connecting the thyroid cartilage, and related organs by Saunders (1964)
• when vocal folds have been drawn apart, they are said to be **abducted**

• when vocal folds have been drawn together, they are said to be **adducted**

The neutral mode of phonation:

• vibration of the vocal folds is periodic, efficient, and without audible friction
The Pathological Voice:

• the description of pathological voice attempts to be universal and is based primarily on abstract laryngeal functions

• the most common systems of pathological voice description concentrate on the degree of hoarseness

• in Germany the ‘RBH-system’ (Nawka, Anders 1996) based on three perceptual dimensions in commonly used:

  → hoarseness
  → roughness
  → breathiness
Assessment of Voice quality:

- **clinical evaluation of dysarthria** including history of speech disorder, evaluation of oral, pharyngeal and laryngeal anatomy, sensory and motor function, behavioral, language and cognitive assessment, evaluation of respiration, volume capacity, perceptual ratings on voice quality, evaluation of rate of diadochokinetic rate, articulation and prosodic structures

- **acoustic measurements** including the parameters: fundamental frequency, jitter, shimmer and harmonics-to-noise ratio

- **electroglottographic measurements** including the parameters: contact quotient and speed quotient
3. Idea and Hypothesis

- research findings suggest that swallowing ability and speech performances are closely related
- the relationship between speech and swallowing has apparently not yet been directly investigated
- of special interest: investigation of what dysphagic characteristics are most highly correlated with changes in acoustic and electroglottographic correlates of speech

**Hypothesis:** If the vocal folds do not close during swallowing and thus do not protect the airway from entering of material, there should also be a disturbance in the glottal behavior during phonation measured by perceptual, acoustic and electroglottographic analysis!
What does the Literature say?

Literature supporting my Hypothesis:

• B. Martin et al. (1990)
• J. Ryalls et al. (1999)
• J. Horner et al. (1988)

Literature NOT supporting my Hypothesis:

• G. Kennedy (1993)
4. Getting started

Criteria for inclusion and exclusion:

- Native language: German
- Neurogenic dysphagia/dysarthria
- No speech disorder that is not neurological (ENT-operation, neck-dissection...)
- No tracheal tube
- Ability to read a short passage and participate in the testing
- Neurological etiology: first insult, lesion site: no limitation
- Neuroradiological proof of the neurological disorder (CT or MRT)
- Time post onset: 2 to 6 months
Number of Patients:

- with dysphagia only: 30 male and 30 female subjects
- with dysphagia and dysarthria: 30 male and 30 female subjects
- age- and sex-matched control subjects: 60 males and 60 females

Evaluation of:

- history of dysarthria and dysphagia
- clinical evaluation of dysarthria and dysphagia
- acoustic measurements on sustained phonation
- electroglottographic measurements on sustained phonation
- videofluoroscopy
5. Preliminary investigation

Methods:

• Six male subjects with severe neurogenic dysphagia and mild to severe dysarthria

• Six age- and sex-matched normal controls

• production of sustained vowels /a,i,u/

• Voice quality was investigated by means of perceptual ratings, acoustic analysis and electroglottographic measurements

• Tests carried out on all neurological patients: bedside swallowing evaluation, radiological confirmation of aspiration, clinical evaluation of dysarthria
Results:

- Group comparisons revealed higher perturbation values and lower harmonics-to-noise ratios in the acoustic analysis of clinical subjects.

<table>
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<tr>
<th></th>
<th>Jitter /a/</th>
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<th>Jitter /u/</th>
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<td></td>
<td>Shimmer /a/</td>
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• Group effects could be found with respect to glottal closing behavior proved by the contact quotient: lower ratios of the Contact Quotient in the EGG signal of the patients

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Discussion:

• no statistical tests were calculated due to the small number of subjects
• no patients with dysphagia only (without dysarthria) were examined, differences could possibly be caused by dysarthria only
• no re-tests after an interval of therapy were taken yet

• If preliminary data proof true:
  → meaningful relationship between dysphagia and specific aspects of the acoustic and electroglottographic signal
  → a non-invasive method which can be applied very quickly and extend the assessment of diagnosing and controlling dysphagia in daily practise