Bioimpedance based measurement system for a controlled neuro-prosthesis

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Swallowing

- Vital process

- Highly complex control

- Conscious and unconscious (reflex)

- Synchronised with breathing

## Dysphagia – Swallowing Disorders

- Aspiration (to choke on sth.) → pneumonia

- Malnutrition and dehydration

- Main cause: stroke - 25% in chronic stage

- Treatment for severe swallowing disorders

  - Feeding tube

  - Tracheal cannula

- Reduced quality of life

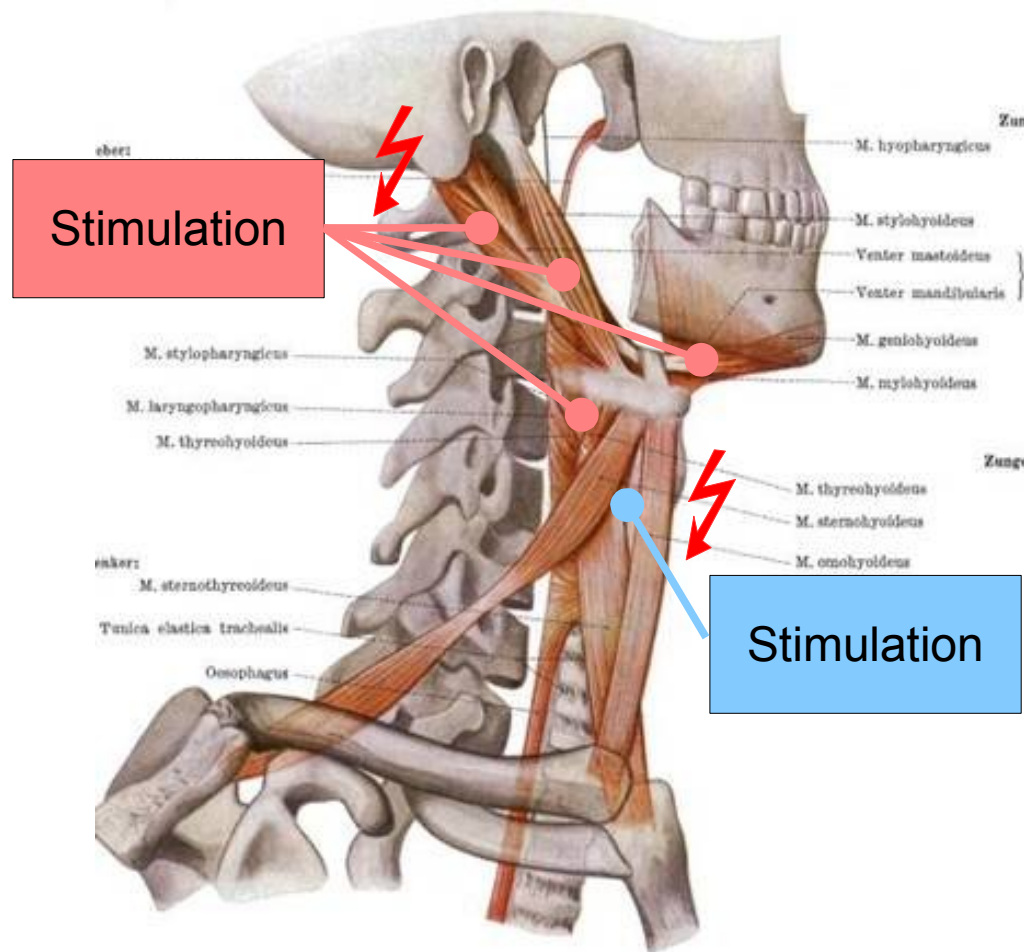- High financial costs for health system
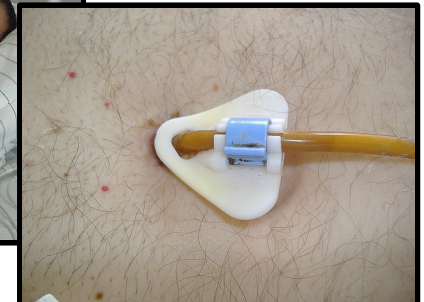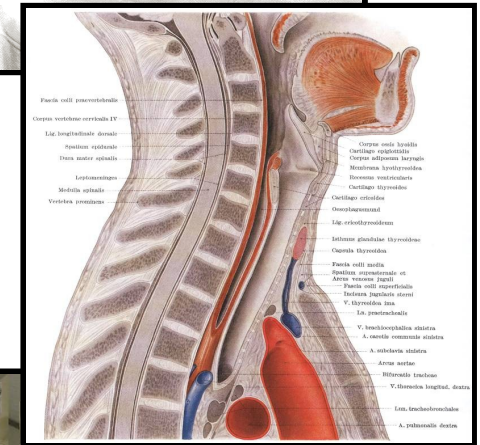
Protection of the upper airway

- Elevation of the larynx

- Flipping of the epiglottis

    → to close the entrance to the trachea

- Closure of the vocal cords (60 %)

- Opening of the esophagus

- Inhibition of breathing
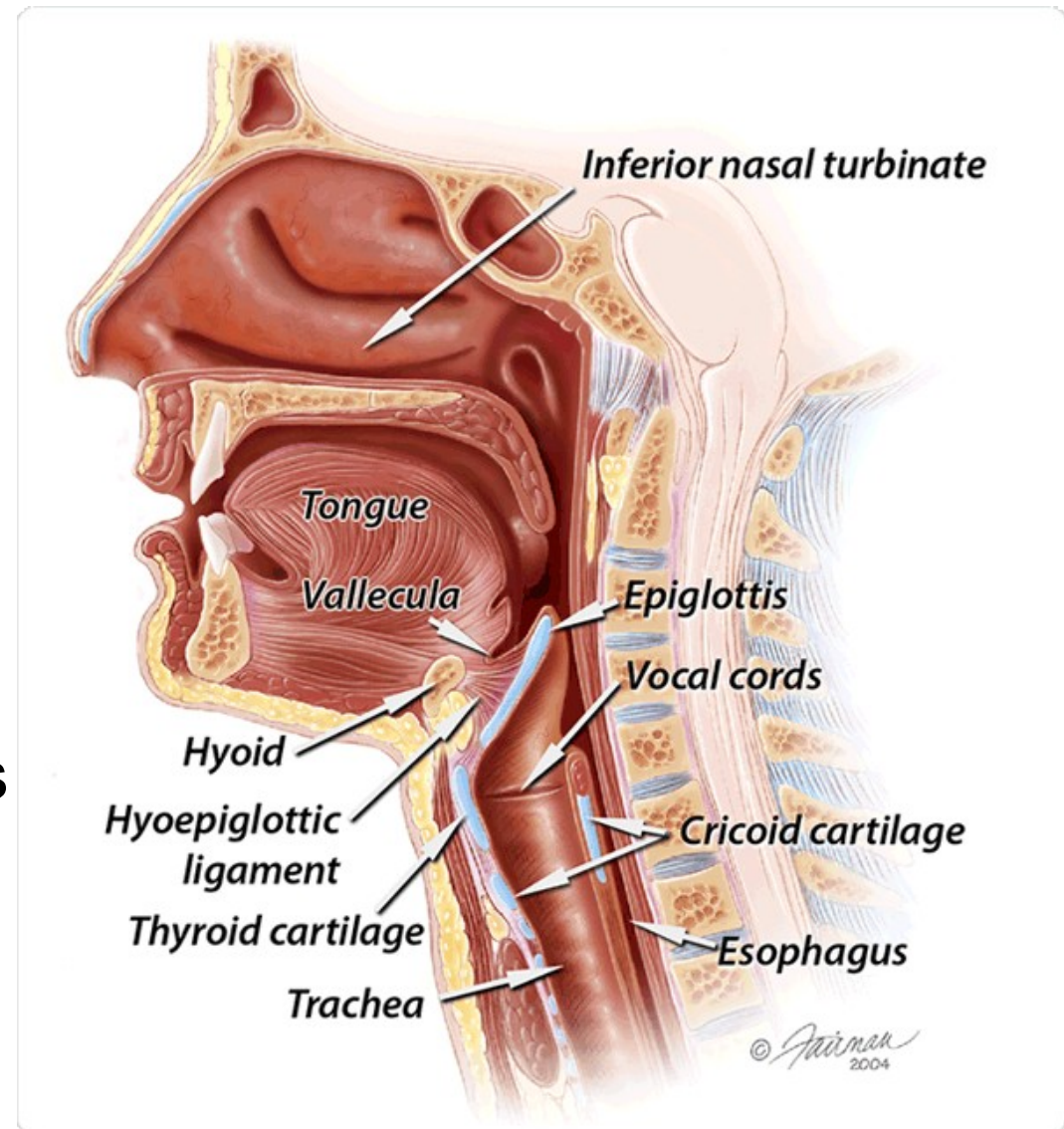
Neuro-prosthetic approaches to support swallowing (implants)

- Artificial activation of muscles involved in swallowing
  - Stimulation of the extrinsic muscles of the larynx to elevate the larynx
  - Stimulation of intrinsic laryngeal muscles to close the vocal cords
- **Drawback of existing systems:**
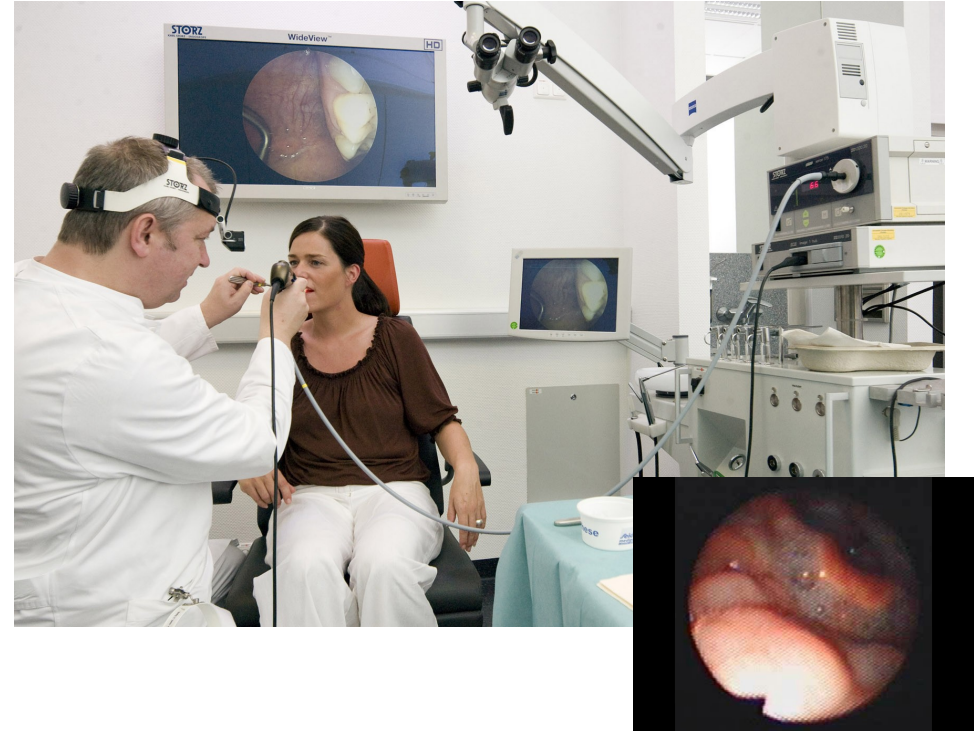 - No observation of success of stimulation and
  - no closed-loop control

State of art in swallowing diagnosis
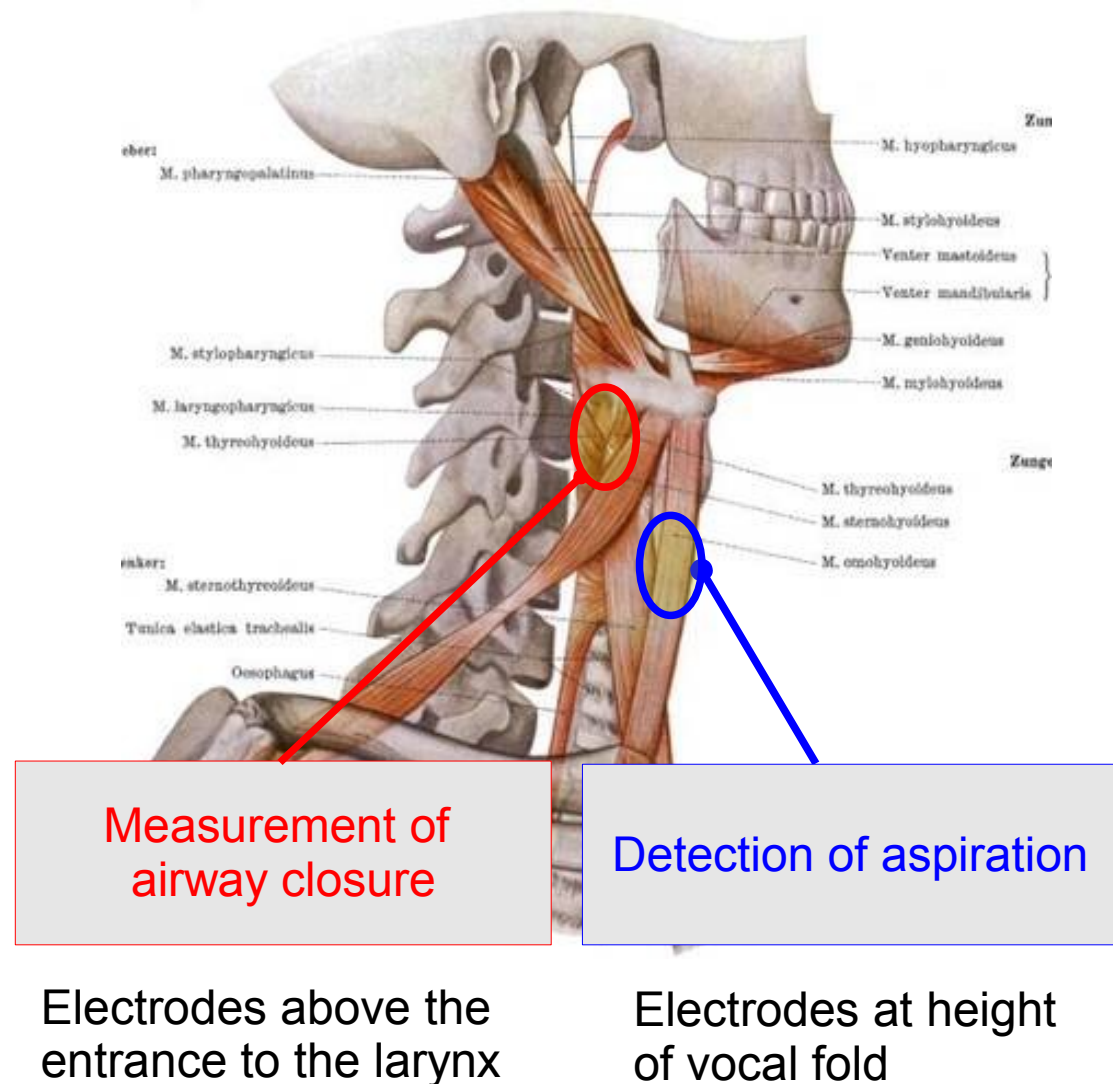
Videofluoroscopy

Endoscopy

- Complex, expensive and bulky devices

- Exposure to radiation during videoflouroscopy

- Only applicable in clinical environments

- Not suitable for controlling swallowing implants in daily life
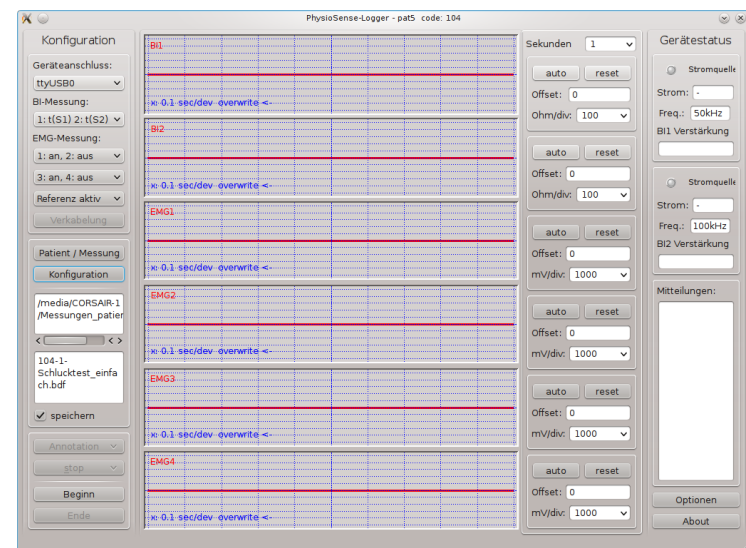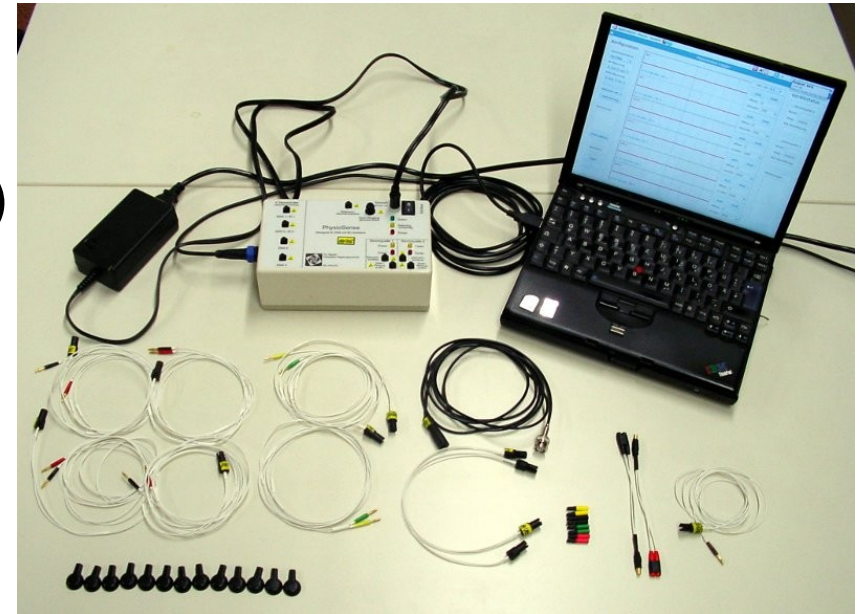
Bioimpedance-monitoring to assess swallowing

- External measurement system certified for clinical use

- Use of needle electrode to prove concept of BI-controlled swallowing neuro-prosthesis

- Transcutaneous measurement for biofeedback applications, diagnosis ...

Measurement of airway closure

Detection of aspiration

Electrodes above the entrance to the larynx

Electrodes at height of vocal fold
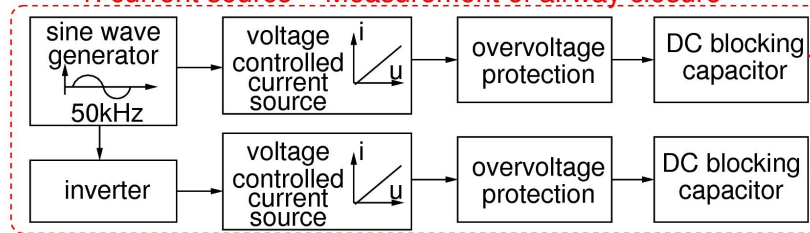
BI-Measurement Device

- 2 Current sources (50kHz, 100kHz)

- 2- and 4- point measurement of BI

- Up to 2x BI & up to 4x EMG

  - Stimulation safe

  - Automatic setting of current and gain for BI measurement

- EN 60601 type BF

- Needle / surface electrodes

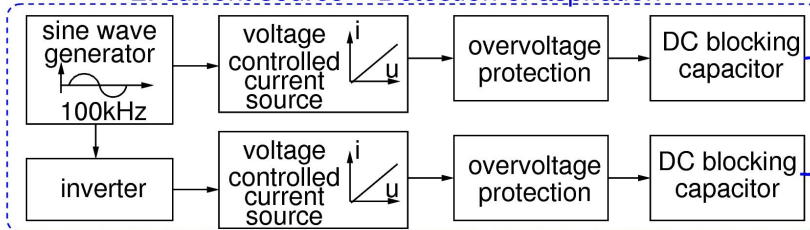- 4kHz sampling time

- Realtime (USB)

BI-Measurement Device
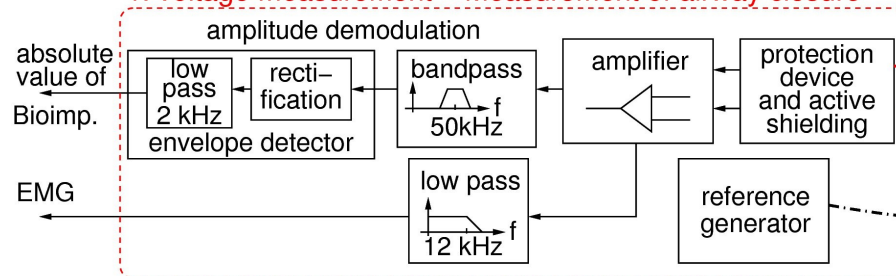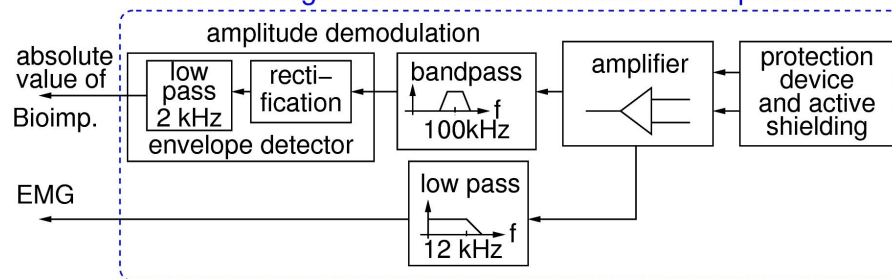

1. current source – Measurement of airway closure

sine wave generator 50kHz → voltage controlled current source → overvoltage protection → DC blocking capacitor

inverter → voltage controlled current source → overvoltage protection → DC blocking capacitor

galvanic isolation

2. current source – Detection of aspiration

sine wave generator 100kHz → voltage controlled current source → overvoltage protection → DC blocking capacitor

inverter → voltage controlled current source → overvoltage protection → DC blocking capacitor

1. voltage measurement – Measurement of airway closure

amplitude demodulation

absolute value of Bioimp. ← low pass 2 kHz ← recti–fication ← bandpass 50kHz ← amplifier ← protection device and active shielding

envelope detector

EMG ← low pass 12 kHz

reference generator

2. voltage measurement – Detection of aspiration

amplitude demodulation

absolute value of Bioimp. ← low pass 2 kHz ← recti–fication ← bandpass 100kHz ← amplifier ← protection device and active shielding
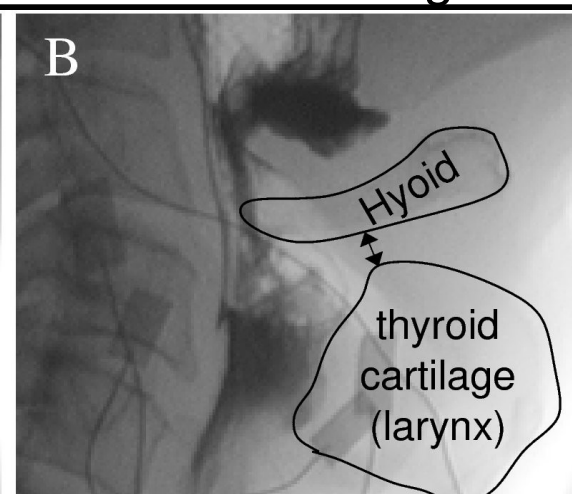
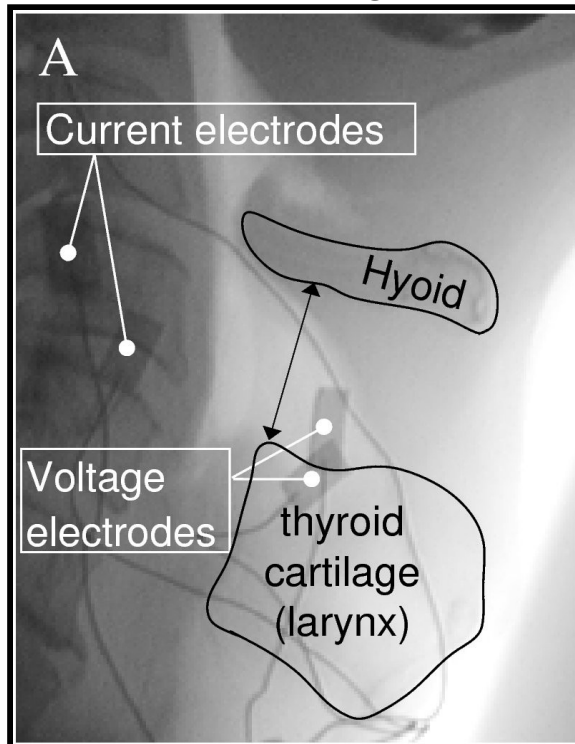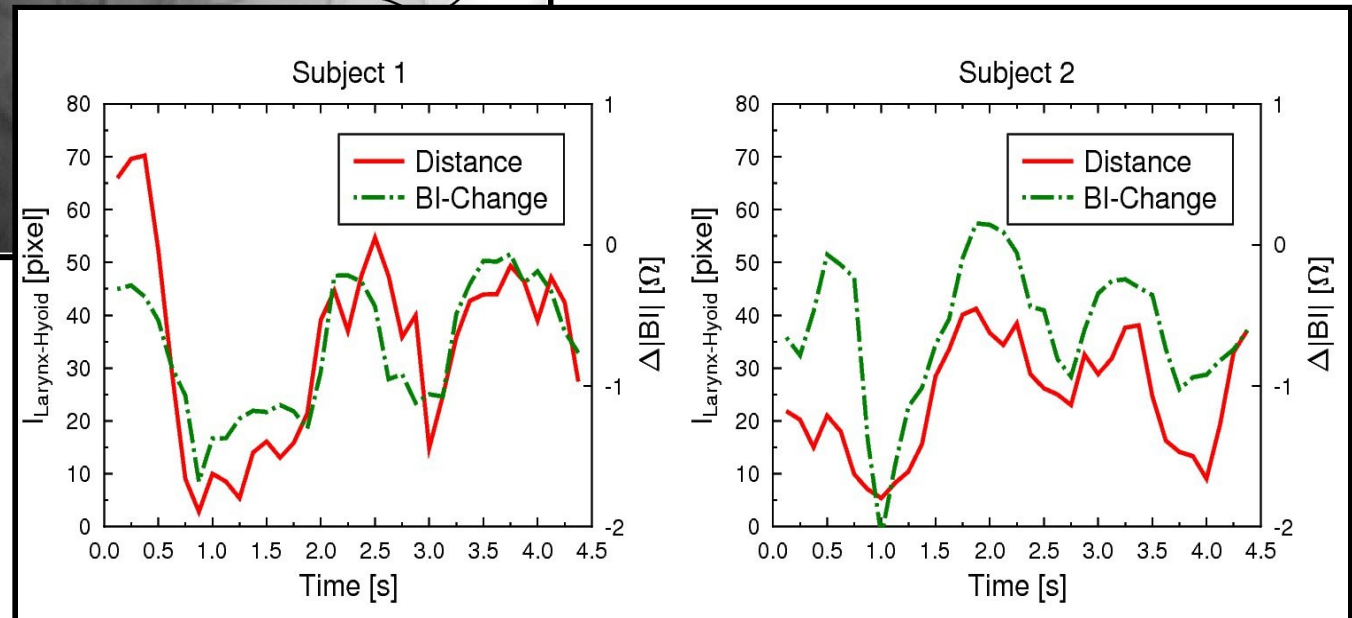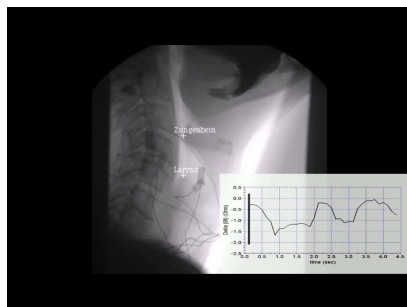envelope detector

EMG ← low pass 12 kHz

Assessment of airway closure
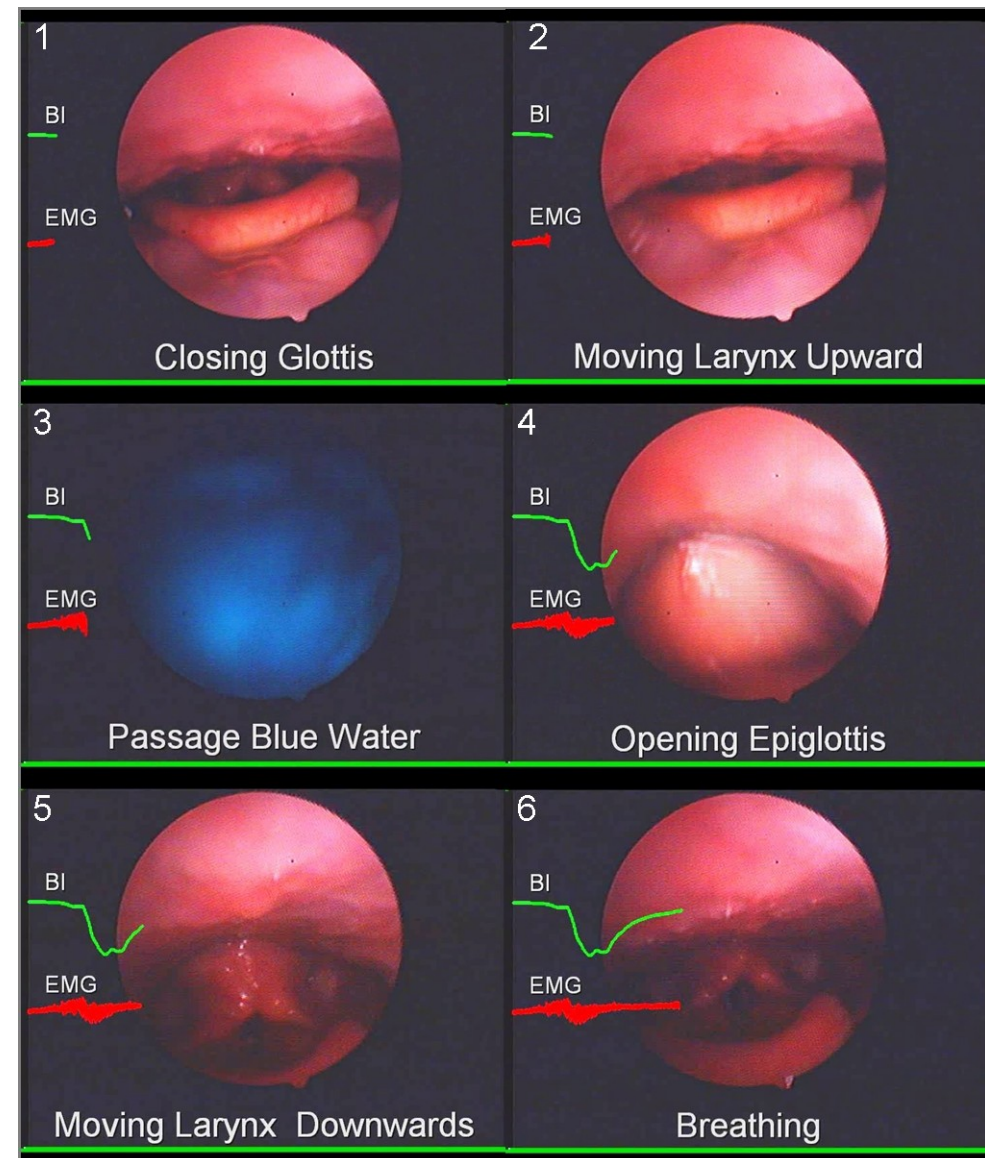

Breathing

Swallowing

- Pilot study with two subjects

- Changes in absolute value of BI compared to the distance of larynx and hyoid as a measure of airway closure
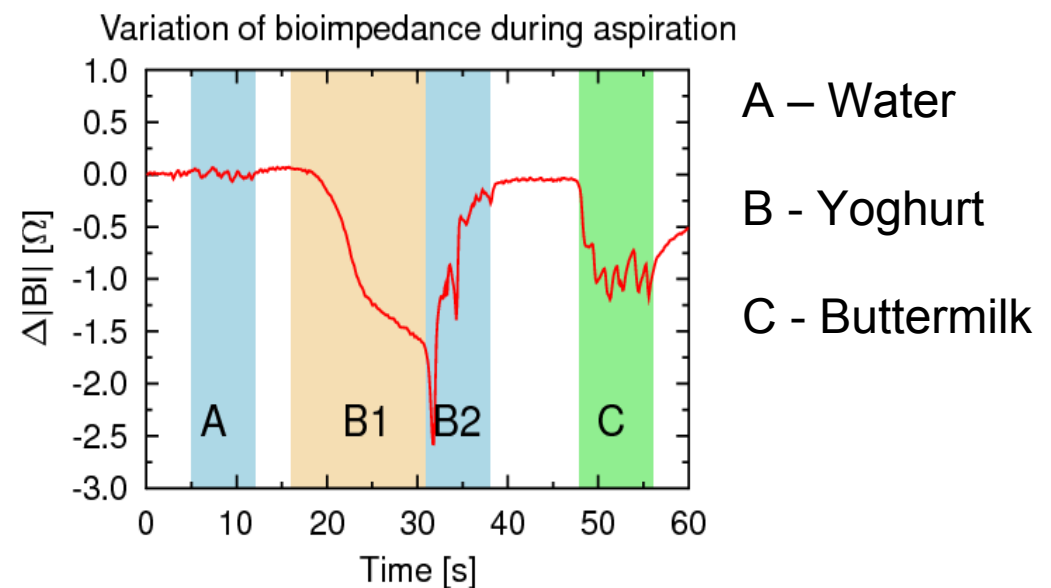
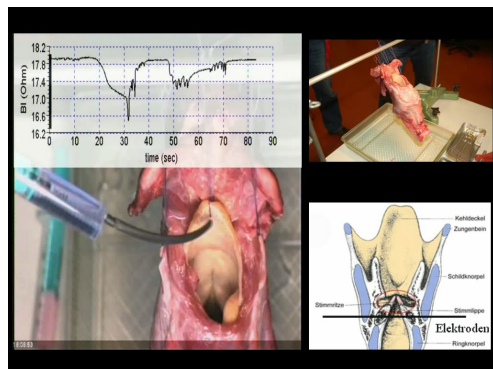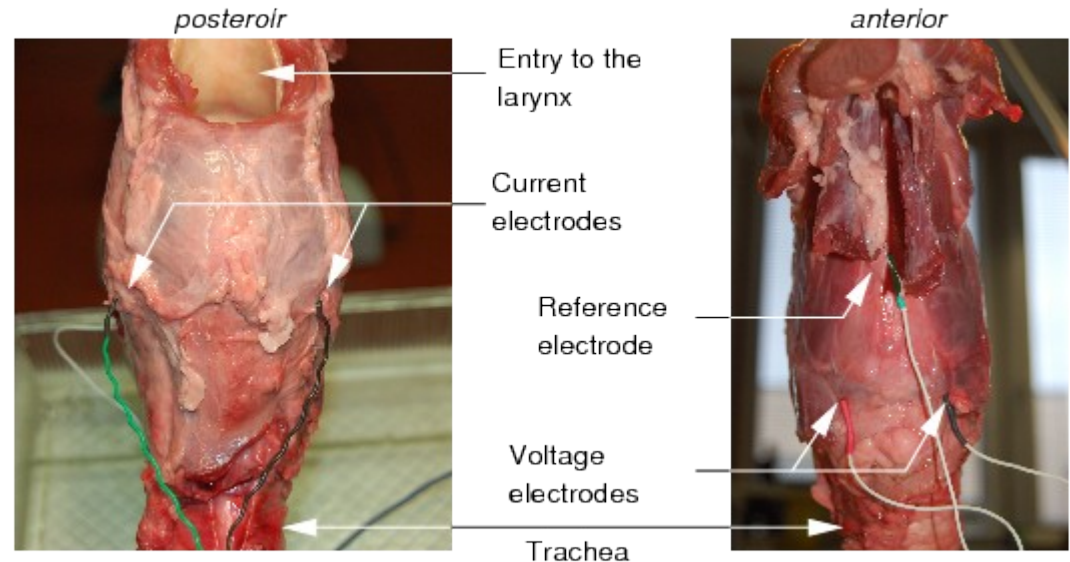# Assessment of airway closure

- Pilot study with one healthy subject

- Comparing of BI-measurement with an endoscopy

1 — Closing Glottis
2 — Moving Larynx Upward
3 — Passage Blue Water
4 — Opening Epiglottis
5 — Moving Larynx Downwards
6 — Breathing

Detection of Aspiration

- Feasibility test on a cow larynx

- Strong changes in BI could be detected

posterior / anterior

Entry to the larynx
Current electrodes
Reference electrode
Voltage electrodes
Trachea

Variation of bioimpedance during aspiration

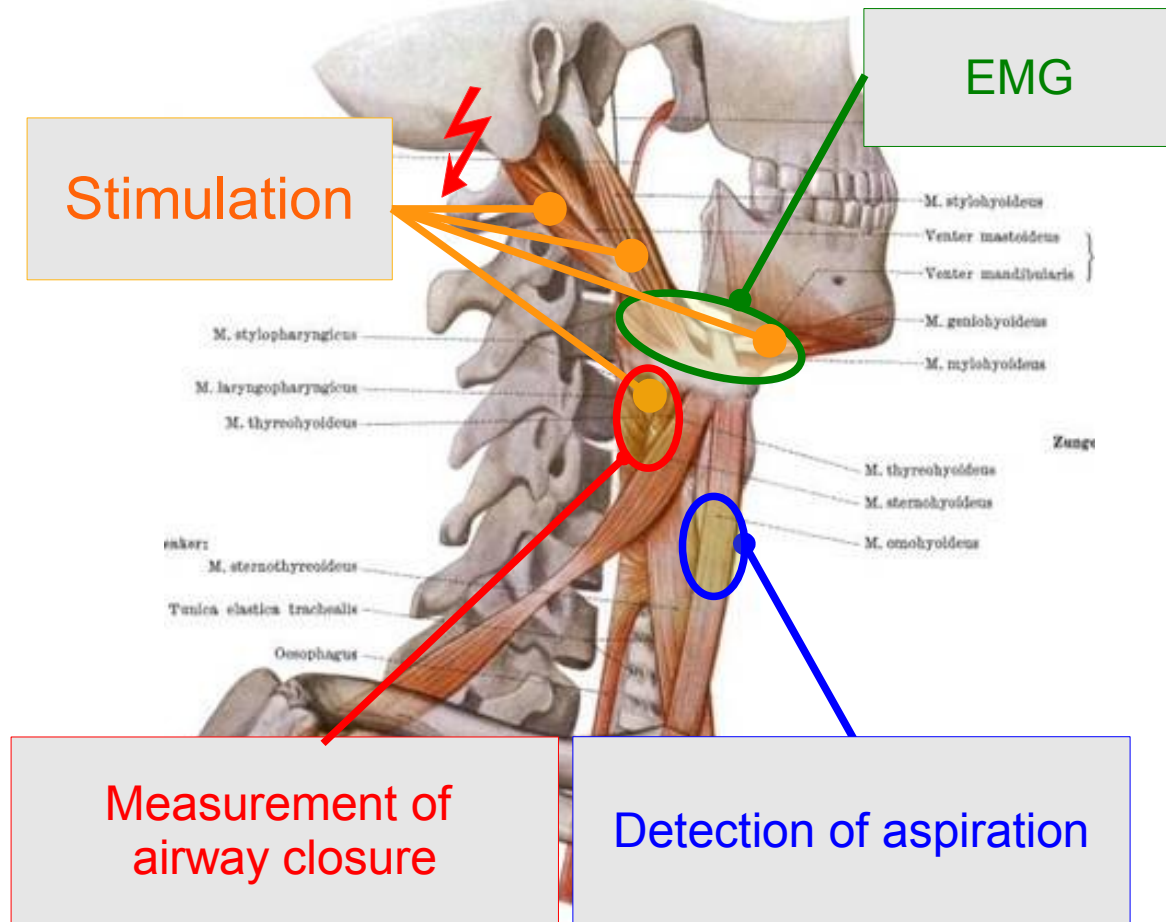A – Water

B - Yoghurt

C - Buttermilk

Concept of a controlled swallowing neuro-prosthesis

Support of swallowing by:

1. Detection of swallowing start by EMG & BI

2. Stimulation of outer laryngeal muscles

3. Monitoring of swallowing success by BI

4. Adjustment of the stimulation

5. Eventually detection of aspiration and triggering of a protective cough

Conclusions

- Simple assessment of swallowing and aspiration

- Use to control implants

- Use for biofeedback and diagnosis

Future Work

- Clinical studies to validate BI

  - Comparison with endoscopy and videofluoroscopy

- Feasibility study on a BI-controlled neuro-prosthesis using needle electrodes and external measurement and stimulation systems

Acknowledgements

- Thanks for your attentions!

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