THE PHARYNGOESOPHAGEAL SEGMENT DURING PHONATION IN PATIENTS FOLLOWING TOTAL LARYNGECTOMY SURGERY

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Abstract
Introduction and aim:
The precise biomechanics of “trachoesophageal (TE) voice” following total laryngectomy surgery are unknown. Pharyngoesophageal (PE) segment vibration has been shown to play a key role in TE voice quality [1]-[3]. Our aim was to study the phenomenology of the PE vibration activity, during TE phonation.

Methods:
A high resolution manometry (HRM) catheter (25 sensors 1cm intervals) was positioned transnasally to span the pharynx and proximal oesophagus in 9 patients that had undergone total laryngectomy surgery. Patients vocalised during concurrent recording using HRM and video-fluoroscopic (VF) (Fig1). Vibration within PE segment was located from VF cine-loops. The pressure gradient (ΔP) was calculated as the difference between the pressure in the upper oesophagus and 2cm above the vibration segment.

A 2D axisymmetric finite element model was built using COMSOL Multiphysics v5.0 (Fig 3). Comparison was made between models of a sphincter with 2.5mm and 5mm radius. Two reference points were set in the middle of the sphincter: one in the middle of the air chamber to measure the pressure, and the other in the inner membrane of PE to measure its displacement ("+" direction denoted movement away from rotational axis).

Results:
Notable findings were: 1) In all patients the speech quality was deemed intelligible. The anatomical location of maximal vibration at the PE segment ranged between the fourth and sixth cervical vertebrae. The average ΔP varied from 6–55mmHg during phonation among subjects (Fig2). 2) Both models exhibited strong initial vibration, but with a 2.5mm sphincter, the vibration was not sustained beyond 0.21 sec. As the sphincter radius was enlarged to 5mm, PE displacement became more prominent with vibration persisting throughout the 1-second simulation (Fig 4).

Conclusions:
This preliminary study is the first to use computer modelling to investigate PE segment biomechanics during TE voice. This experimental and modelling technique shows promise in determining biomechanical factors relevant to phonation following total laryngectomy surgery and to identify predictors of TE voice quality.

References
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Figure 2: Significantly different pressure gradient ($\Delta P$) in the pharyngoesophageal segment across the vibration section among patients ($n=9$, $p<0.01$).

Figure 3: Geometry of PE segment: the materials (in black) and boundary conditions (in blue) are listed. Two red dots represent the position of the reference points: one in the air chamber for measuring the pressure and the other in the inner membrane for measuring the displacement. $r$ is the radius of the sphincter.

Figure 4: Results of air pressure and displacement of the membrane taken at the reference points. Left and right columns respectively represent the model results with a 2.5-millimetre- and a 5-millimetre-wide sphincter.