Abstracts - MEMRO 2006, Zurich July 27-30, 2006
4th International Symposium on Middle Ear Mechanics in Research and Otology

P10

Hyperelastic warping applied to x-ray micro CT images for the study of human middle ear chain deformations under static pressure load

SL. Gea[1], SA. Maas[2], WF. Decraemer[1], H. Maier[3], JJ. Dirckx[1],
Antwerp; Belgium[1], Utah; USA[2], Hamburg; Germany[3]

In everyday life the human ear is subject not only to sound but also to slow, quasi-static pressure variations with amplitudes orders of magnitude larger. The middle ear provides a mechanism to protect the inner ear from these excessive static pressures while at the same time it is able to process the sound signals. In the present study we investigated how the ossicular chain deforms and changes its 3-D configuration when acted upon by large static pressures. Fresh human temporal bones were within 60 hours post mortem used for the present experiments. Pressure ranging from -200 daPa to + 200 daPa was applied in steps to the external ear canal using a pressure generator. At each pressure step a scan of the entire temporal bone was recorded using an in-vivo x-ray micro CT scanner (Skyscan 1072). To determine with good precision the small deformations of the ossicular chain we use 'hyperelastic warping' (HEW, Rabbitt et al., 1995 SPIE 2573:252), a deformable image registration method. In this relatively new technique a 3-D finite element model, based on careful segmentation of a template dataset at zero pressure, is being deformed (warped) until it aligns with a target dataset at a different pressure. Results of HEW were compared to more crude results obtained by aligning 3-D models, made by individual segmentation at each pressure step, using an Iterated Closest Point (ICP) algorithm. ICP calculates the translation and rotation between two models at successive pressure steps. With this technique the ossicles are presumed to behave as rigid bodies, a restriction that is not required in the warping technique. ICP and HEW show similar results. The absence of significant strains in the ossicles proofs further that the rigid body assumption is quite valid. 3-D displacement of the ossicles will be shown in an animation and expressed mathematically by plotting the displacement of a few landmark points as a function of pressure. The immediate screw axis for the motion of each individual ossicle was also calculated for each pressure step. The position of this axis along with the rotation about this axis and the slide along this axis are also shown as a function of pressure. This leads to a description of the changes in configuration and slippage in the ossicles explaining the protecting mechanism of the middle ear.