Transmission of bone-conducted sound in the human skull based on vibration and perceptual measures

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II Eeg-Olofsson M, Stenfelt S, Granström G. Implications for contralateral bone-conducted transmission as measured by cochlear vibrations. Otology & Neurotology 2011;32:192-198.

III Håkansson B, Reinfeldt S, Eeg-Olofsson M, Östli P, Taghavi H, Adler J, Gabrielsson J, Stenfelt S, Granström G. A novel bone conduction implant (BCI): Engineering aspects and pre-clinical studies. International Journal of Audiology 2010;49:203-215.

IV Eeg-Olofsson M, Stenfelt S, Taghavi H, Reinfeldt S, Håkansson B, Finizia C. Transmission of bone conducted sound – correlation between hearing perception and cochlear vibration. Manuscript.

Transmission of bone-conducted sound in the human skull based on vibration and perceptual measures

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ABSTRACT

For patients who are rehabilitated with bone conduction (BC) hearing aids, the position on the skull of the hearing aid is critical for the perception of the sound. The aim of this work was to describe the vibration of the cochlea from BC sound stimulation at different positions on the skull. The relevance of the vibration velocity of the cochlea as a perceptual measure was also investigated.

In human cadavers vibration stimulation was applied at eight positions on each side of the skull with a frequency range of 0.1-10 kHz. The resulting velocity of the cochlear vibration was measured by a laser Doppler vibrometer from both ipsilateral and contralateral stimulation. A prototype of a novel bone conduction implant (BCI), positioned approximately 5 mm behind the ear canal, was tested with the same methodology. In live human subjects vibration stimulation was applied at four positions on the head. The resulting vibration velocity of the otic capsule was measured with a laser Doppler vibrometer. Bone conducted hearing thresholds in the same subjects were compared to the otic capsule vibration results.

With vibration stimulation on the ipsilateral side there was an increased magnitude response of the cochlear vibration with shorter distance between the stimulation position and the cochlea. When the bone conducted stimulation was on the contralateral side the change in magnitude of the cochlear vibration between positions was limited. BC stimulation at a position close to the ipsilateral cochlea increased the response magnitude difference between the cochleae. Results were similar when stimulating with the BCI as with a BC transducer. The influence of the squamosal suture on BC sound transmission was not clear but indications of a small damping effect were found. With simultaneous bilateral stimulation at the low frequencies correlated signals were added constructively or destructively while non-correlated signals gave a 3 dB sound energy increase. Time separation between ipsilateral and contralateral stimulation was found to be largest at positions close to the cochlea. The velocity response at the otic capsule from BC stimulation was similar between human cadavers and live humans. In live humans the correlation between vibration of the otic capsule and hearing perception was low at the individual level, while median data showed similar trends between the two methods.

When BC sound stimulation is applied at a smaller distance between the stimulation position and the cochlea, sound transmission improves to the ipsilateral cochlea and is decreased to the contralateral cochlea. Measures of the vibration of the otic capsule from BC sound stimulation as an estimation of BC hearing perception was investigated and the results indicate that the method is valid. A patient with a hearing loss where there is an indication for BC hearing aids can likely benefit from increased ipsilateral stimulation, and also an improved binaural hearing from bilateral stimulation, when the hearing aid is applied close to the cochlea. The BCI is a realistic alternative to other BC hearing aids.

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