Hayo Breinbauer-Krebs

Dr. med.

**Definition of surgical landmarks and insertion vectors as orientation guides for cochlear implantation by means of three- and two- dimensional computed tomography reconstructions of temporal bones**

Fach/Einrichtung: Hals-Nasen-Ohrenheilkunde
Doktorvater: Prof. Dr. med. Mark Praetorius

**Background**: Cochlear implantation is a technique where an electrode array inserted on the scala tympani of the human cochlea may stimulate the structures of the inner ear directly, thus overcoming a sensorineural hearing loss. As this field continues to develop, new challenges arise on relation to damaging the cochlear inner structures as less as possible during electrode insertion, an effort that may allow not only the utilization of residual hearing on hybrid electro-acoustical cochlear implants, but may represent a key aspect in allowing the expression of the full potentiality of an human-machine interface in restoring one of human fundamental senses. One aspect which may contribute to a minimally traumatic surgery relates to the alignment of the electrode insertion vector to the architecture of the initial segment of the spirally shaped organ of the cochlea.
**Aims**: To describe the orientation and particular characteristics of the initial segment of the cochlea, on a sample of cochlear implant candidates, in the context of an insertion vector based on a cochleostomy and a round window implantation approach. Then, to propose a "straight-forward" method to first estimate an ideal insertion vector on an individually patient basis without the need of complex three-dimensional reconstructions, and then to translate this orientation to an applicable procedure based on intra-operative landmarks.
**Material and Methods:** CT-scans of temporal bones of 51 cochlear implant candidates (for a total of 100 included ears) were collected. Three dimensional reconstructions of those temporal bones were analyzed focusing on multiple anatomical features influencing insertion vectors: 1) Ideal insertion following the centerline of the initial segment of the cochlea, 2) Ideal insertion vector following a round window approach and parallel to the outer wall of the cochlea on its initial segment, 3) Architecture of the hook region, 4) Indirect estimation of the orientation of the basilar membrane by means of assessing the line connecting opposite points of the first turn of the cochlea . A protocol for measuring insertion parameters on simple 2D CT-scans images was proposed, and was applied twice with an at least 3 week time interval (for test-retest reliability assessment). Results of both two and three dimensional strategies were compared for validity assessment.
**Results:** After correcting radiological data with true anatomical planes (true mid-sagittal plane and Frankfort plane), the average centerline of the initial segment of the cochlea on the sample can be described as having a 63° angle on the axial plane (with the mid-sagittal line as reference) and having a 7° angle on the coronal plane (with the horizontal line from left to right as reference). The ideal insertion vector considering a round window approach was in average 7° apart from this centerline (significant difference, $p<0,001$), with an average 62° angle on axial plane, and 5° angle on coronal plane. More importantly a large dispersion was found on insertion vectors along the sample, with as much as 60° of difference between subjects. This dispersion was larger in the usually less assessed sagittal

component, distributing as a “narrow-band” following a long axis parallel and slightly lateral to the vertical segment of the facial nerve. The later finding highlighted the need of an individually applicable estimation protocol. This was achieved by describing the insertion vector with two points: the insertion point (pivotal point of the vector at the cochleostomy or round window) and a point where the vector intersects the virtual plane of the posterior tympanotomy. This second point was successfully described as distances to two easily recognizable landmarks during surgery: the short process of the incus and the vertical segment of the facial nerve (inferred in relation to the medial wall of the posterior tympanotomy). Mean distances to incus and facial landmarks were 3,4 mm and 1 mm for the centerline/cochleostomy approach and 4,2 mm and 0,6 mm for the round window approach. Acquiring these distances based entirely on simple 2D computer tomography scans was found to be a reliable (0,83 to 0,96 intraclass correlation coefficients on test-retest) and a valid (0,62 to 0,84 intraclass correlation coefficients when comparing 2D measurements with the 3D “gold standard” assessment) method for estimating the insertion vector on a patient to patient basis. Additionally, the orientation of the basilar membrane of the initial segment of the cochlea was successfully estimated by 2D and 3D strategies in relation to the round window, incudostapedial articulation and short process of the incus landmarks, with similar reliability and validity statistical values. Finally, a scenario where an over-extended hook region interfered with a round window insertion vector was found of 5% of the sample.

**Discussions**: Although further histological and navigation-assisted studies should be carried to confirm these results, the method here proposed appear to be a valid and reliable way of estimating ideal insertion vectors for a cochlear implantation, depending only on standard radiological images normally solicited for every candidate. This notion during surgery may contribute to the effort of achieving an as atraumatic insertion as possible under the philosophy of hearing and structure preservation in cochlear implantation.