O. Majdani, R. Heermann, C Dullin, Th. Lenarz, M. Leinung

Flat panel volume CT based high precision navigated interventions at the lateral skull base

Purpose:
To date, minimally invasive surgery for cochlear implantation has not been possible due to the limited resolution of current imaging procedures. With the upcoming technology of flat-panel-based volume CT (fpVCT), a detail resolution of ~ 150 µm can be achieved which should be sufficient to display even substructures of the cochlea including inner structures of the cochlea. It can also be used to determine the position of the cochlear implant electrode array in relation to the modiolus wall and the basilar membrane.

Method:
Imaging. Five cadaver heads were scanned in an experimental fpVCT device (GE Medical Systems, USA). It features two flat panel detectors consisting of 1024 x 1024 detector elements each on an area of 20.48 x 20.48 cm^2, resulting in a detector element size of 200 x 200 $µm^2$. The scan field of view in the X/Y plane was 13.5 cm to cover the entire specimen. The used scanning parameters were empirically derived in earlier experiments to optimize image quality for high resolution in temporal bones.

Navigation. For intraoperative navigation the VectorVision[2] (BrainLAB, Germany) was used. The route to the scala tympani using a transmeatal posterior fossa cochleostomy approach was planned after important structures such as facial nerve and sigmoid sinus had been segmented manually using the software iPlan 2.0. The fiducial-based registration of the specimens was used at the beginning of the navigated procedure. The position of five titanium miniosteosynthesis screws implanted beforde imaging was identified in the volume dataset. For registration their real position was indicated by the pointer. A referencing adapter was fixed to a medical drill prior to calibration.

Surgery. The preoperatively defined trajectory was followed by the surgeon using the navigated handheld drill, which was positioned along the planned drilling route with the entry point in the retroauricular region and the target point in the scala tympani right anterior to the round window niche. Postoperatively, fpVCT imaging was acquired so as to subtract preoperative imaging and to reveal the correctness of the drilling canal's position. In addition, the temporal bones were drilled out as for a regular cochlear implantation (mastoidectomy and posterior tympanotomy, identification of the facial recess) and the drilled route was documented. Special attention was given to any possible collateral damage on adjacent functionally important anatomical structures.

Results:
It was possible to identify all critical structures with the necessary accuracy within the imaging datasets in all five specimens. The calculated error of the system was 0.1 mm in 3 cases and 0.2 mm in 2 cases. The surgical procedure itself took about 10 to 15 minutes with interposed pauses in order to minimize thermal stress in vicinal nerval structures. The trajectory to the cochlea could be determined without injuring any of these structures. The scala tympani was opened as intended at the planned location of the cochlea.

Conclusion:
This feasibility study demonstrates that intraoperative navigation based on high resolution imaging enables high precision surgical procedures at the lateral skull base. Five cadaver experiments comprising a mastoidotomy and cochleostomy were performed without any collateral damage to vicinal structures such as facial nerve, chorda tympany or sigmoid sinus. These experiments were carried out the a navigated and hand-held medical drilling device. We expect further increase of surgical accuracy by the use of a mechatronic assistance device especially when surgery will be performed *in vivo*. The minimal invasive cochlear implantat surgery described above still demands solutions for correct insertion of the intracochlear electrode, which is work in progress.

Key words:
cochlear implant surgery, navigation, robotic assistance device, minimal invasive surgery, high precision surgery