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Robotic guided minimally invasive cochleostomy: first results

Purpose:
Cochlear Implant (CI) surgery for treatment of deafness is performed by implanting a stimulating multielectrode array device into the inner ear (cochlea). Since there are many functionally important anatomical structures in the temporal bone area, e. g. facial nerve and sigmoid sinus, prior to the opening of the cochlea (cochleostomy) the relevant structures need to be exposed by the surgeon, thus they serve as landmarks for correct positioning of the cochleostomy which is extremely important in order to achieve optimum postoperative outcome. In this time-consuming exposition nerval structures run the risk of being damaged by the surgical procedure.
In principle, a *minimally invasive* CI surgery could be performed by targeting the inner ear from the retroauricular region o the cochlea by drilling a single canal through the temporal bone without damaging relevant structures. The fault tolerance of this high-precision surgery is less than 0.5 mm. This benchmark is not available by current navigation devices so far, which is predominantly due to the limited resolution of current imaging procedures.

Method:
High resolution imaging of a harvested temporal bone specimen was acquired using a flat panel based volume CT (GE, USA) and transferred to a VectorVision2 Navigation System (BrainLAB, Germany). Surgical planning included the segmentation of all anatomical structures which needed to be preserved and definition of a trajectory starting from the retroauricular region and ending at the round window niche (software iPLAN2.5, BrainLAB).
An industrial KR3 device (KUKA, Germany, 6 dof, serial kinematics) served as robotic device. The interface software for communication of the robot and navigation system was the software package VVlink (BrainLAB). A medical drill was attached to the end effector.
After registration with osteosynthesis screws the tip of the drill at the top of the robot arm was calibrated. The robot was activated to move along the defined path while the position of the robot and the specimen was controlled by the navigation system.
Pre- and postoperative CT-imaging was superimposed so as to visualize the result. Fusion and postop CT scans were merged using the iPLAN2.5 software. The planed trajectory was transferred to the fusioned scans and the accordance of the trajectory and the drilled tunnel as well as the position of the cochleostomy were visualised.

Results:
The position of the bony canal and of the cochleostomy coincided with the course of the planed trajectory. The cochleostomy was performed at the designated position. There was no damage to any of the risk structures. Surgical planning and installation of the integrated navigation-guided robotic drilling device required ~45 mins, the procedure itself was done in less than 5 minutes.

Conclusion:
Our preliminary results show how to perform a minimally invasive cochlear implant procedure using a robot device. A canal from the surface of the skull to the inner ear was drilled using a robot under control of a navigation system without applying any damage to vicinal structures. The preparation time is still too long, but can be reduced for standard procedures in the future.

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