Use of image-guided techniques to access the endolymphatic sac

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Introduction

- Meniere’s disease affects 3.5 to 513 per 100,000, many of whom have unpredictable and debilitating episodic vertigo altering their ability to carry out activities of daily living.1,2
- Initial therapy is medical management with low-salt diet, avoidance of caffeine and alcohol, treatment with diuretics and steroids. Intratympanic administration of steroids have also been used in the treatment of acute symptoms.3
- Surgical options vary widely depending on residual hearing in the affected ear with endolymphatic sac decompression typically being the first-line surgery.4 Success rates vary from 33-94%, with the majority between 60-70%.5,11 However, as many as 33% of sacs were not properly identified at the time of decompression in a post-mortem analysis of the temporal bones, suggesting failure of this procedure may be related to inadequate decompression.5
- Use of image-guidance to identify and decompress the endolymphatic sac may improve the likelihood of surgical success.

Methods

- Six human cadaveric temporal bones were used in this study.
- Techniques similar to those used for percutaneous cochlear implantation were applied to this study.

Step 1: Implantation of Bone-Anchored Fiducial Markers

Three fiducial markers are bone-implanted on the lateral skull around the mastoid. Typical location includes the mastoid tip, the suprachalreal region, and the region posterior to the sigmoid sinus.

Step 2: Acquisition of CT Scan

CT scan of the temporal bone was obtained using a clinically-applicable protocol.

Step 3: Trajectory Planning

The location of the endolymphatic sac is extrapolated from the location of the vestibular aqueduct on the CT scan. A drill trajectory is manually determined such that a drill bit can safely approach the sac without injuring the facial nerve, jugular bulb, and posterior canal. Custom planning software with three-dimensional visualization capability is used for this planning.

Step 4: Design and Fabrication of Customized Microstereotactic Frame

A custom microstereotactic frame, called the Microbot, is designed and fabricated to mount on the fiducial markers and constrain a drill bit along the desired path.13

Step 5: Cortical Mastoidectomy and Visualization of the Endolymphatic Sac.

A cortical mastoidectomy is performed with identification of the facial nerve. The sigmoid sinus and jugular bulb are decompressed and the endolymphatic sac is exposed.

Step 6: Attachment of Frame and Validation of Drill Trajectory

The Microbot is attached to the fiducials and a 1 mm drill bit is passed through the Microbot to confirm that the planned trajectory safely approaches the endolymphatic sac.

Step 7: Intraoperative Photodocumentation

A 0° Hopkins rod is inserted through the side to photodocument the location of the drill bit in relation to the endolymphatic sac.

Results

On the right, the location of the endolymphatic sac in six temporal bones is outlined in blue. The location of the planned trajectory via the image-guidance technique is identified by the drill bit.

- The endolymphatic sac was correctly targeted in all cases.
- In one bone, two candidates for the endolymphatic sac could be seen (outlined in red and blue) during the mastoidectomy. However, after further exposure of the posterior canal, it was demonstrated that the blue structure was indeed the sac, which was correctly identified by image-guidance.
- Only a pinpoint area can be targeted although the surface area of the endolymphatic sac is significantly larger. This cannot be predicted from the CT scan.

Discussion

- Demonstrated successful identification of the endolymphatic sac on CT by linear extrapolation from the vestibular aqueduct using image-guided techniques.
- Successful identification of linear trajectories to the endolymphatic sac without injury to critical adjacent structures.

Future Directions

- New methods will be required to determine the boundaries of the sac as total decompression of the sac has been associated with a more successful outcome. Perhaps co-localization with T2-weighted MRIs may assist in identification of the borders.
- Normal temporal bones were used in this study. Imaging studies of patients with Meniere’s disease will be needed to determine feasibility of generating a linear trajectory without injury to adjacent structures in these patients. Prior anatomical studies have shown that in such patients, the space between posterior canal, jugular bulb, and facial nerve has a much smaller area (24.8 mm² vs. 47.0 mm²) with limited exposure to the endolymphatic sac without decompression of the sigmoid sinus and jugular bulb.13

References