Real-time Volume Rendering to Predict Surgical Access in Cochlear Implantation

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INTRODUCTION

- Cochlear Implantation (CI) with Round Window (RW) insertion is performed via mastoidectomy and facial recess dissection[1].
- Assessment of RW access by Computed Tomography (CT) is limited by standard 2D reformatted views[2].
- Commercial surgical planning software calculates cochlear duct length[3], yet no capability exists to measure anatomic relationships between the RW and the facial recess.
- Volume Rendering is a 3D reconstruction technique allowing 3D reformatted views from any perspective[4].
- Herein, we propose a novel 3D modality using a game engine that predicts RW accessibility with virtual views of the facial recess.

METHODS

- A pilot study evaluated feasibility of volume rendering of CT imaging to accurately represent anatomy. Virtual renders were compared to physical views using 3D printed patient-specific models (Figure 1).
- Subjects comprised 3 CT temporal bone series with 1 mm slices. From these, virtual and physical models were created.
- An Unreal Engine app was developed using visual scripting and C++ code. DICOM data imported with native support.
- Volume rendering with raymarching implemented an open-source plug-in[5].
- A virtual camera projected 3D anatomy from a microsurgical view. Planar cropping of the volume enabled visualization through a virtual facial recess to identify the RW.
- Physical models were manually-segmented, 3D printed, and dissected in a training laboratory.
- The St. Thomas' Hospital (STH) classification for RW accessibility was used to compare surgical views of virtual and physical models[6].

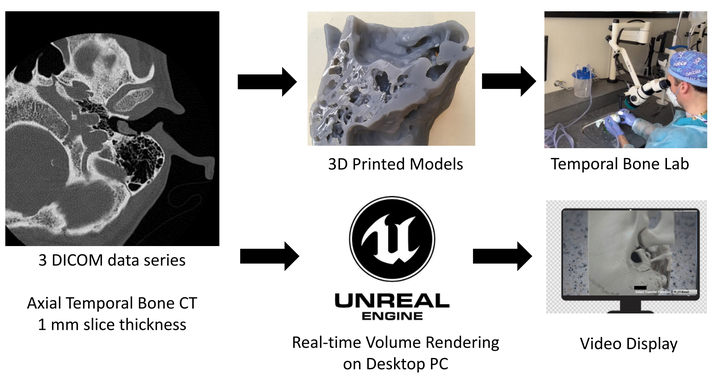

Figure 1. Three CT scans were used to make both virtual and physical models for comparison.

RESULTS

- DICOM data from 3 CT temporal bone series were imported directly into Unreal Engine as volume textures.
- Volume rendering with multiple light sources was successfully executed in real-time using raymarching.
- All volume renders were oriented in the surgical position and planar cropping resulted in identification of the RW in all 3 subjects (Figure 2).
- 3D-printed models were drilled to expose the RW with a mastoidectomy and facial recess dissection.

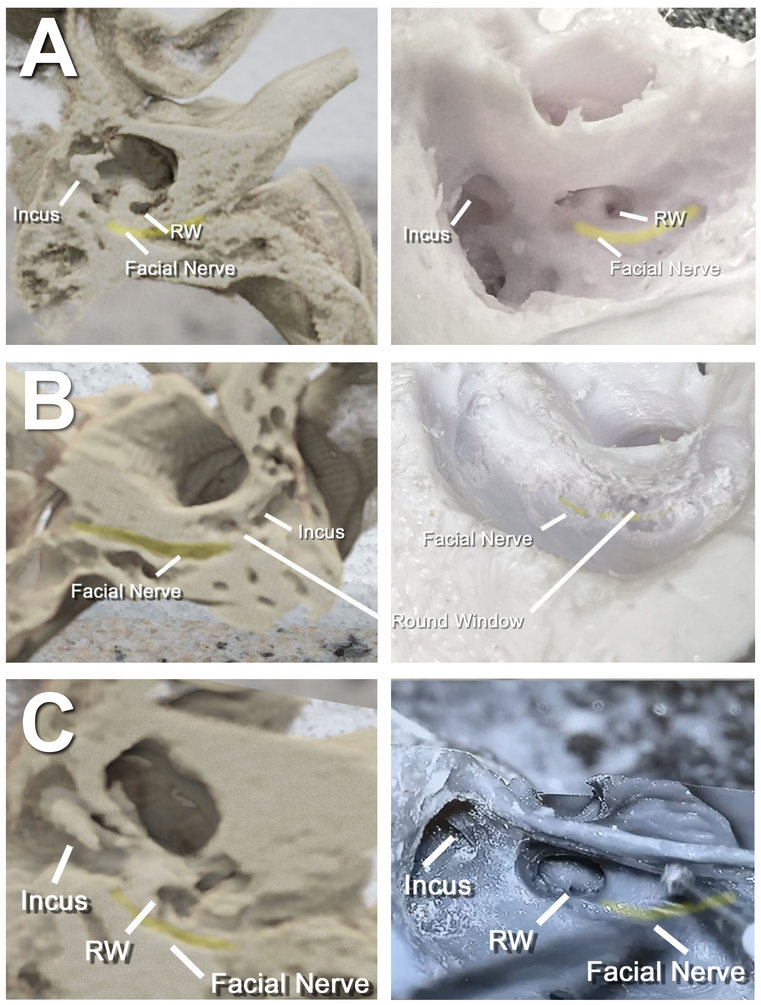

Figure 2. Comparison of virtual (left) and drilled out 3D-printed models (right) for subjects 1 (A), 2 (B), and 3 (C). Planar cropping of volume renders recreated surgical views through the facial recess to view the round window.

RESULTS

- All anatomic landmarks were identified in volume renders.
- Subject 1 had full visualization of the round window in both virtual and physical views (STH Type I).
- Subjects 2 and 3 had less than 50% of the RW visualized in both virtual and physical views (STH Type IIb).

DISCUSSION

- A novel desktop software application successfully projected raymarched volume renders that demonstrated similar anatomic relationships to those encountered with microscopic visualization of 3D printed models.
- All three subjects had matching STH classification types based on physical and virtual views.
- Any CT (or MRI) can be reviewed instantly from any orientation using real-time volume rendering.
- One limitation was the use of 3D printed models for comparison to volume renders, rather than in vivo subjects or cadaveric specimens.
- A second limitation was the lack of virtual dissection around the round window membrane, which increased the risk of error when classifying types using the STH system.
- Current visualization tools only incorporate planar cropping without the ability to remove specific voxels for virtual bony dissection of the mastoid and facial recess.

CONCLUSION

- Volume Rendering in a game engine is feasible to accurately project imaging to predict anatomic relationships.
- Real-time rendering facilitates review of 3D anatomy with near-instant file preparation without segmentation.
- Future studies will compare virtual views to intraoperative findings in CI surgery.

ABSTRACT

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References

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