Surgical Anatomy of the Human Round Window Region: Implication for Cochlear Endoscopy through the External Auditory Canal

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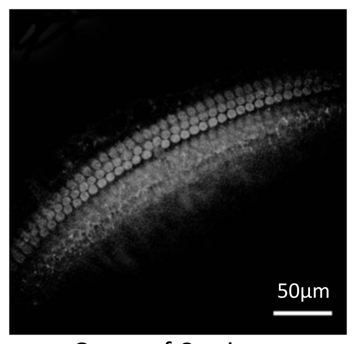
Abstract

Objectives: We have demonstrated, in mice, that optical imaging via two photon fluorescence through the round window (RW) provides unprecedented resolution of unstained cochlear cells and intracellular organelles. Based on these results, we are developing an endoscope for optical imaging of the human cochlea to establish, for the first time, cellular-level diagnosis of sensorineural hearing loss.
Methods: Fifty human temporal bones were studied. Otomicroscopic examination was performed using a transcanal tympanotomy approach. A straight wire was inserted transcanal and bent at the tip to reach the round window membrane (RWM) perpendicularly. The angle of the bent wire was measured, and correlated with the angle calculated from temporal bone CT scans obtained before and after measurements in situ.
Results: The opening of the RW niche was located posteriorly in 6 bone (13%), inferiorly in 18 bones (39%), and posteroinferiorly in 22 bones (48%). Four temporal bones were excluded due to pathology. The angle measured in cadaveric temporal bones correlated well with that obtained from CT scans. The angles ranged from 110-127°, with the median of 115 ° and the middle 50% ranging from 109 ° -119 °. The angles were not statistically different among the three orientations of the RW niche. A parameter that would also influence the design of a rigid cochlear endoscope is the prominence of the tympanomastoid suture line in the external auditory canal.
Conclusions: By correlating measurement from cadaveric human temporal bones and their CT scans, we defined key parameters necessary for design of an endoscope for intracochlear imaging. Our design would enable cell-specific, minimally-invasive, real-time diagnosis in clinic.

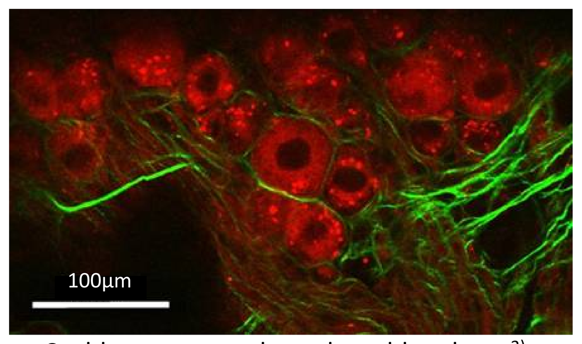
Introduction

Sensorineural hearing loss is the most common sensory deficit worldwide and it most commonly originates from the inner ear. Yet, state of the art clinical imaging of the inner ear today relies on computed tomography (CT) scans and magnetic resonance imaging (MRI), neither of which allow identification of individual cells in the inner ear. Currently the only source of information about the cellular basis of human deafness is autopsy specimens. Clinical audiograms, which are the current gold standard for establishing the degree of hearing loss, are very insensitive – they may be normal even when 80% of cochlear neurons are missing[1)]. There is an unmet medical need to develop diagnostic tools to establish cell-specific, early diagnosis of sensorineural hearing loss while using minimally invasive approaches.

To address that need, we have explored optical imaging of the inner ear because optical approaches provide higher spatial resolution at a lower cost than CT or MRI scans. We have demonstrated, in mice, that two photon imaging through the intact round window provides unprecedented resolution of unstained cochlear cells, including sensory hair cells and cochlear neurons, and their intracellular organelles [2), 3), 4)].



Organ of Corti through the RW[2)]



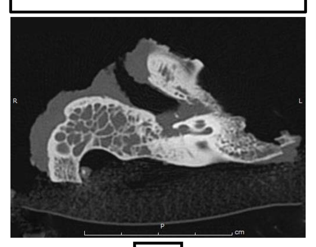
Cochlear neurons through cochlear bone[3)]

Based on these results in mice, we aim to develop an endoscope for optical imaging of the human cochlea through the intact RW to establish, for the first time, cellular-level diagnosis of sensorineural hearing loss. A critical part of the endoscope design is detailed understanding of the anatomy of the RW region. To gain that knowledge, we have studied cadaveric human temporal bones surgically and radiographically. We have defined the range of angles necessary to reach the round window membrane perpendicularly, which will enable intracochlear endoscopy through the round window.

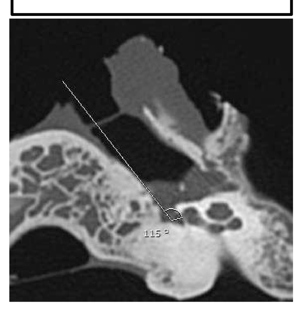
Methods

Cadaveric temporal bone

CT scan



CT measurement



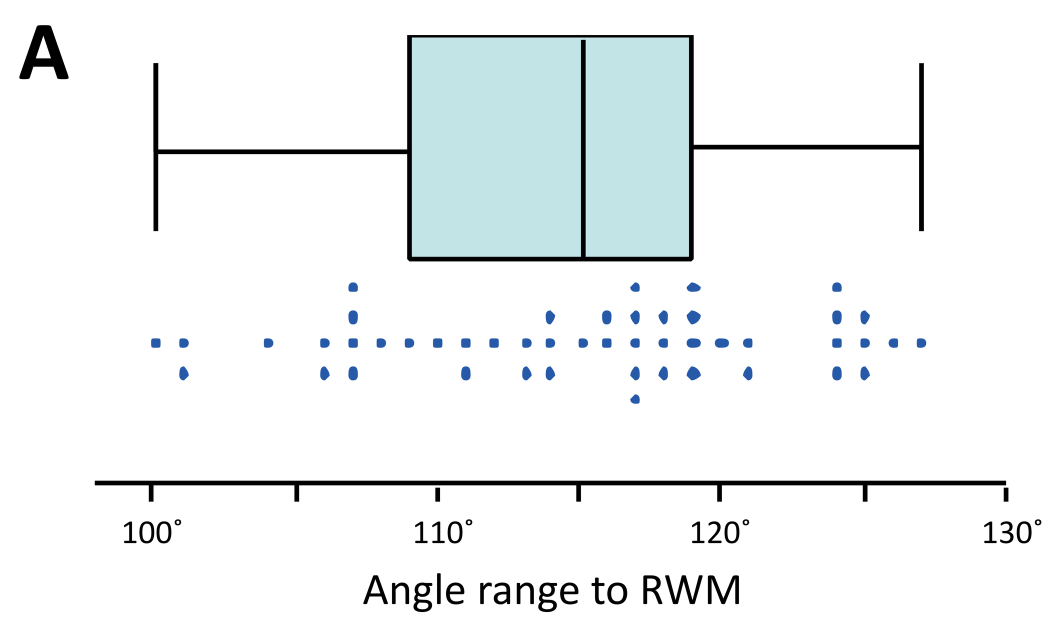
Surgical measurement

1. Measuring transcanal angles to RW membrane in CT scans
Fifty cadaveric human temporal bones with no known otologic disease were studied. Gender and age of the donors were unknown. The bones were imaged using high-resolution CT scans.All scans were reformatted to allow identical horizontal sectioning through a plane with the key anatomical landmarks: basal turn of the cochlea, RW niche, RW membrane, manubrium of the malleus and EAC. This single index section was used to measure the angle to the round window membrane via a straight line through the EAC.

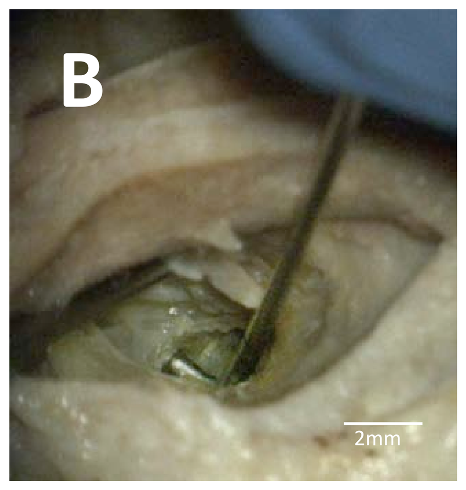
2. Measuring transcanal angles to RW membrane in cadaveric temporal bones
Otomicroscopic examination of the RW region in cadaveric temporal bones was performed using a transcanal tympanotomy approach after elevating a posterior tympanomeatal flap. Four temporal bones were excluded due to adhesive otitis media, EAC cholesteatoma or chronic otitis media with a tympanic membrane perforation. The angulation of the RW niche opening was categorized as inferior, posterior or postero-inferior[5)]. The RW niche was drilled out whenever indicated to expose the RW membrane circumferentially. A straight wire was inserted transcanal and bent at the tip to reach the RW membrane perpendicularly. The angle of the bent wire was measured, and correlated with the angle calculated from temporal bone CT scans obtained before and after surgical measurements.

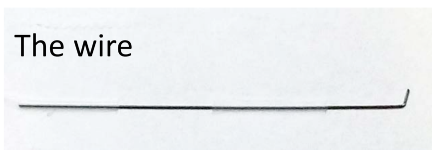
Results

1. Transcanal angle to the RW membrane ranges from 100˚ to 127˚



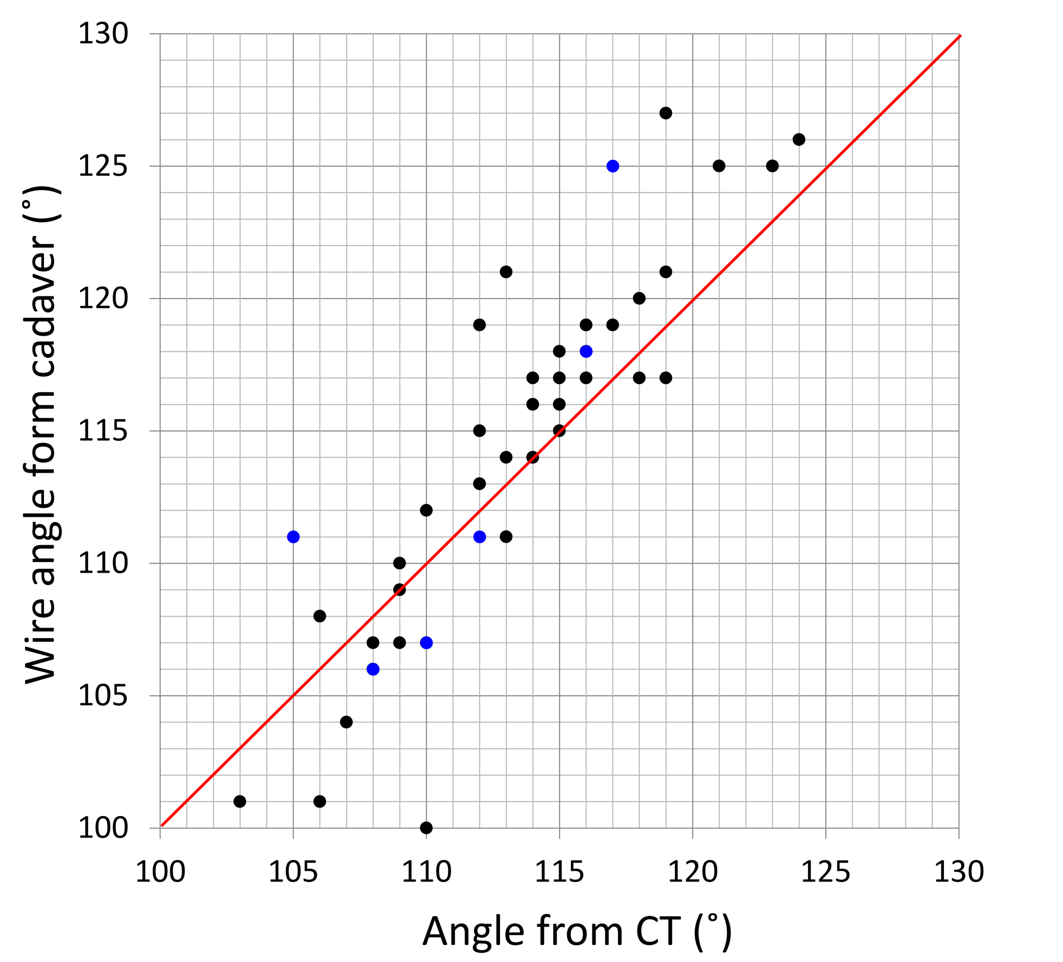
A: Transcanal angle range to RWM. Median is 115˚; 25th percentile is 109˚ ; 75th percentile is 119˚.





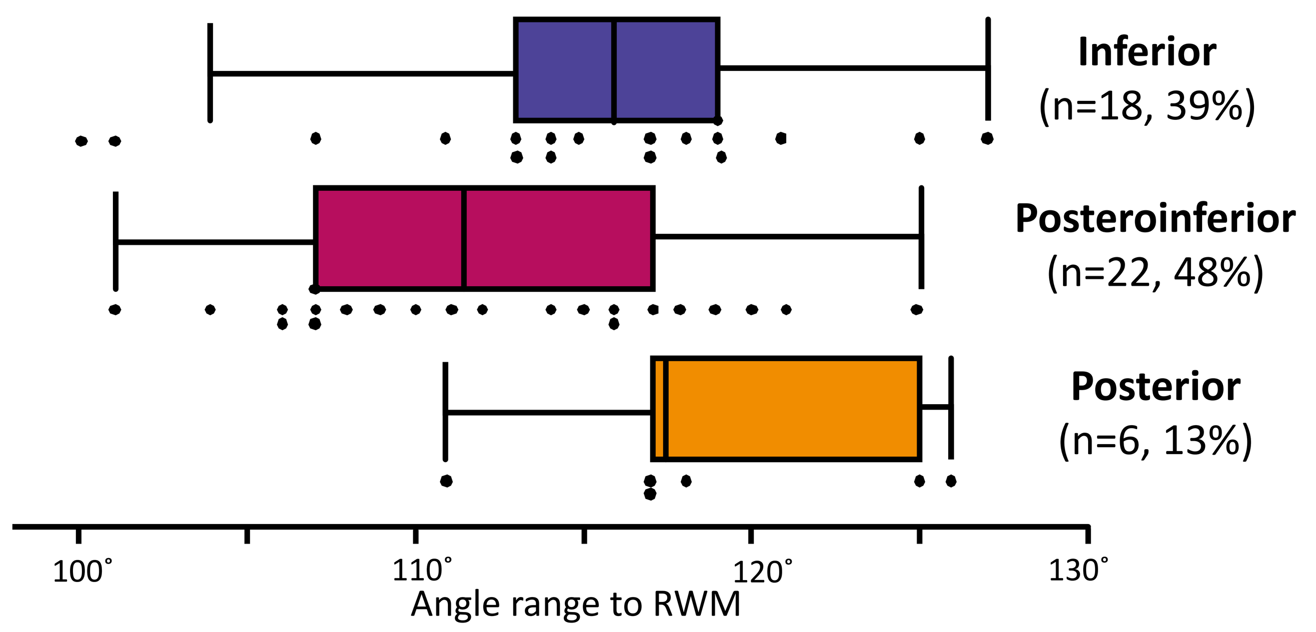
B: A representative measurement of the angle between the straight portion of the wire in the EAC and the bent portion perpendicular to the RW membrane in a cadaveric temporal bone.

2. Surgical and radiographic measurement of RW angulation are in excellent agreement



Surgical measurements in cadaveric temporal bones correlate well with radiographic measurements from the respective CT scans (correlation coefficient 0.89). Blue dots indicate specimens with a prominent tympanomasoid suture line in the EAC, requiring drilling.

3. RW membrane is most commonly located posteroinferiorly



The 25[th] to75th percentile of angles ranged from 117-125˚, 113-119˚ and 107-117˚ for posteriorly, inferiorly and postero-inferiorly opened RW niches, respectively. The differences were not statistically significant among the groups by ANOVA.

Conclusion

We have defined the required angulation of the endoscope for transcanal, transtympanic intrcochlear imaging through the round window membrane. Such angulation could be achieved rigidly, with prisms or flexibly. Cochlear endoscopy has a potential to enable cell-specific, minimally-invasive, real-time diagnosis of cochlear pathology in outpatient clinics.

Acknowledgements

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