Active and Passive Kinematic Gains of the Organ Of Corti Mechanotransduction

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Introduction

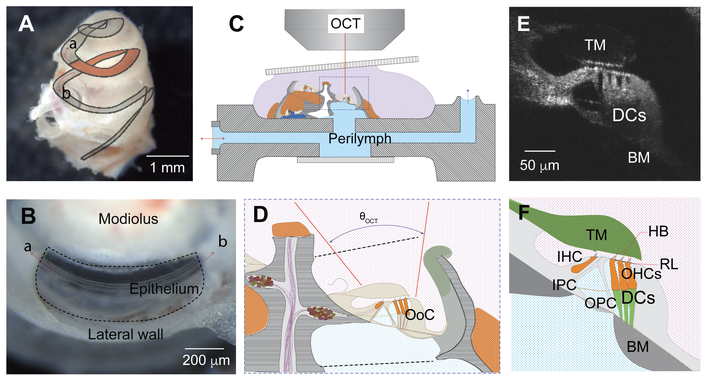
The organ of Corti (OoC) deforms due to two sources of agitation - vibrations of the basilar membrane (BM) and the length change of outer hair cells (OHCs). In vivo, BM vibrations induce shear motion between the tectorial membrane (TM) and the reticular lamina (RL), thereby deflecting the elastically-coupled OHC stereocilia. Deflection of OHC stereocilia modulates the mechanotransduction current and consequently the OHC length. OHCs' length change then further deforms the OoC (feedback loop). The current understanding of OoC micromechanics attributes deflection of both OHC and IHC stereocilia to the shear motion between the TM and RL induced by BM displacement.

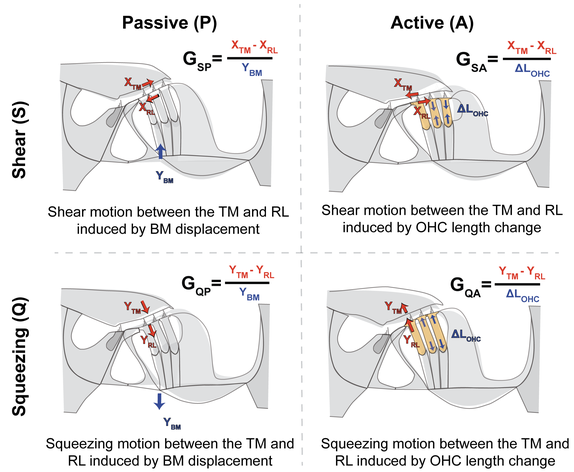
In this study, we analyzed the relative motion of the TM and RL when stimulated mechanically (pressure differences that induce BM displacement), and electrically (voltage differences that induce OHC length change). By separating the passive (mechanical) and active (electrical) response of the OoC, we were able to quantify the kinematic gains that describe how these separate sources of agitation affect the motion of subtectorial space. The kinematic gains have been unknown because: (1) it is not possible to separate the active from the passive mode of OoC deformation in live cochlea, and (2) the resolution needed to confidently resolve the subtectorial space (whose height is 2-5 μm) is currently not attainable for OCT light sources that penetrate through the bone.

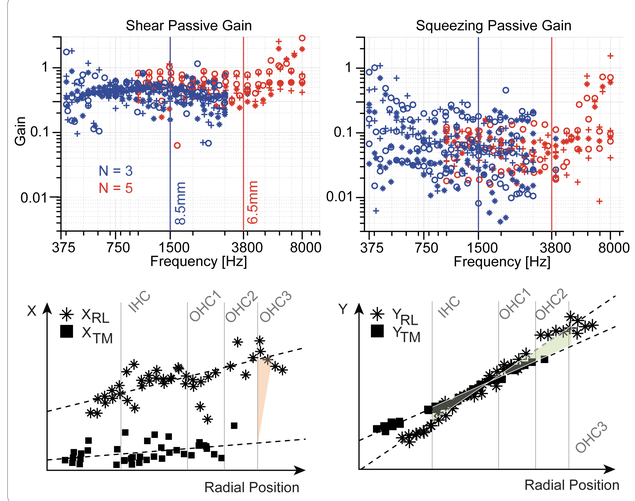
Cochleas were acutely excised from young Mongolian gerbils (15-30 days old, both sexes). Isolated cochleas were reduced by removing the apical and the basal turns leaving the middle turn of which BF ranges 1-4 kHz. The reduced cochlear turns were placed in a custom-designed microfluidic chamber filled with perilymph-like solutions. The cochleas were then stimulated either mechanically or electrically. Using OCT, we measured the OoC vibration response to a multi-tone stimulus at two angles, differing on average by 35 degrees. The collected vibrometry data were then used to reconstruct two-dimensional OoC deformation patterns.

Note that all displacement variables in this poster refer to a local anatomical coordinate system, where Y is the transverse and X is the radial component of the motion.

Experimental Methods

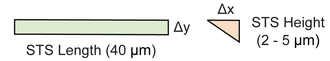


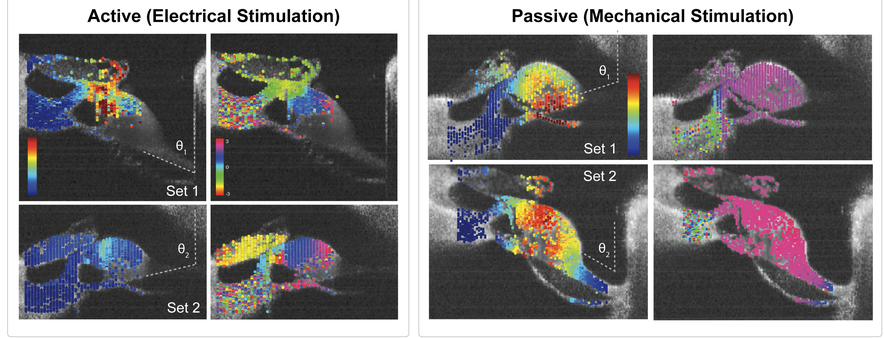


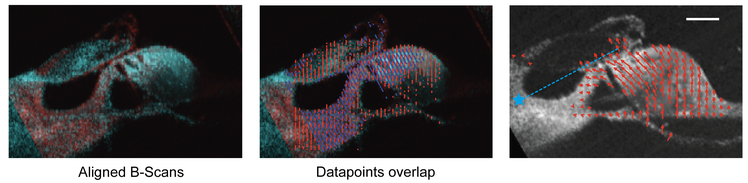


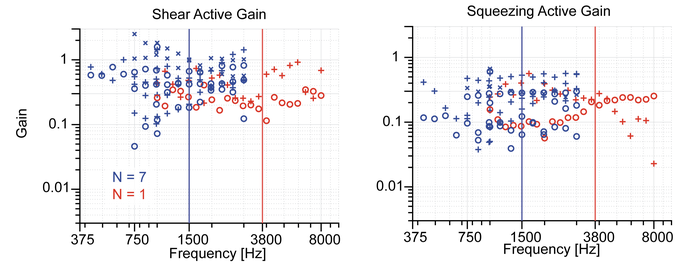
The squeezing gain is smaller than the shear gain - but how small is small?

While the magnitudes of squeezing and shear gains induced by the BM displacement differ almost by a magnitude, direct comparison is not fair when considered as drives to the IHC stereocilia. When the geometric gain is considered, which is higher for the squeezing gain (20-8 times depending on location [*Furness et al. 2008*]) due to the dimensions of the subtectorial space, the squeezing and shear gains become comparable. This indicates that both the shear and squeezing motion matter as driving mechanisms to the IHC stereocilia.









Discussion

In experiments at both 6.5 and 8.5 mm locations, complex motion was observed in the subtectorial space. In addition to the shear passive gain, there is a squeezing passive motion that, despite its low magnitude when compared to the shear gain, is not negligible since the volume of the displaced fluid also depends on the subtectorial space geometry. We measured active gains, for both squeezing and shear motion induced by OHC length change.

Our results show that motion in the subtectorial space is more complex than previously thought. How deformation of the OoC results in motion of subtectorial space may explain the difference between mechanical and neural tuning, especially in the middle and apical turns. This study is an effort to characterize key quantities relating BM and OHC motility as driving mechanisms to mechanotransduction of both IHCs and OHCs.

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