Relevance of tympanic membrane lesion at different locations and of different sizes for the middle ear transfer function

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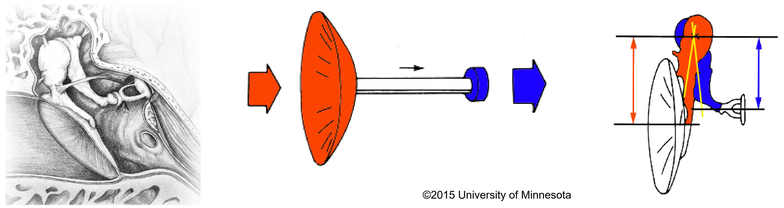
1: Introduction



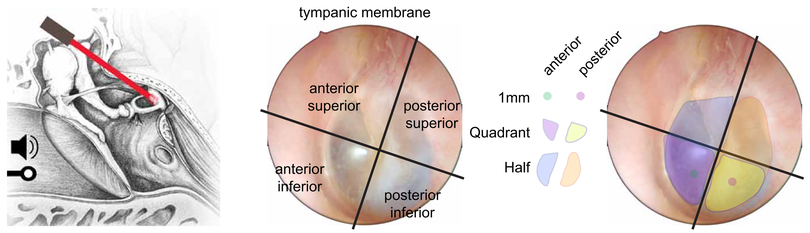
The tympanic membrane represents the boundary between the outer and middle ear and helps to overcome the impedance difference between the fluid filled cochlea and air. [1,2]

2: Hypothese

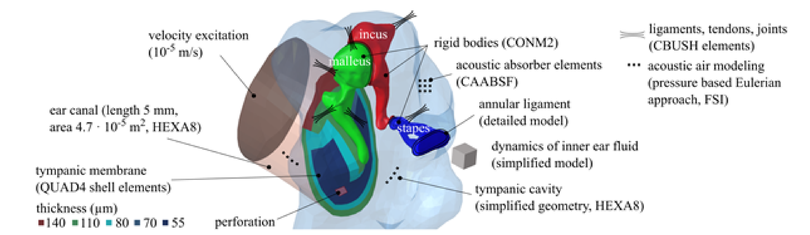
Tympanic membrane lesions can occur as a result of infections, mechanical trauma, chronical diseases or as intentional perforations (i.e. to release middle ear fluids with tubes).

We tested how lesions at different positions and/or sizes are tolerated differently.

3: Methods

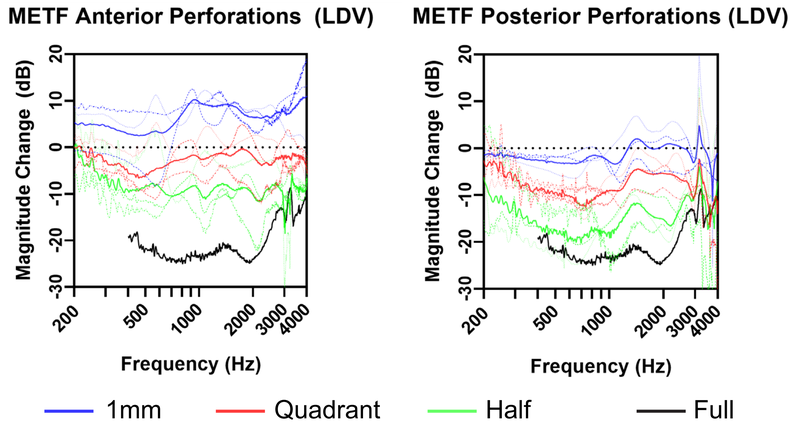


Middle ear transfer function (METF) measurements using LDV in six human temporal bones before and after TM perforations at different locations (anterior or posterior lower quadrant) and to different degrees (1mm, ¼ of the TM, ½ of the TM, and full ablation).



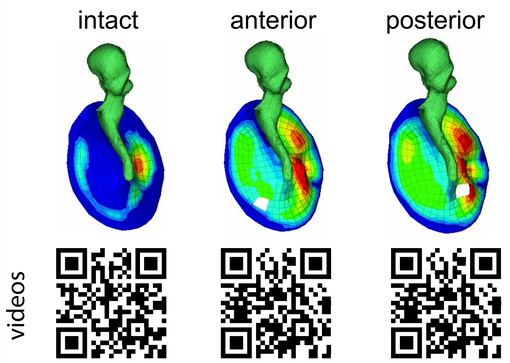
METFs were simulated in a Finite Element (FE) model, similarly altered and compared to the measured METF data. [3]

4: METF measurements

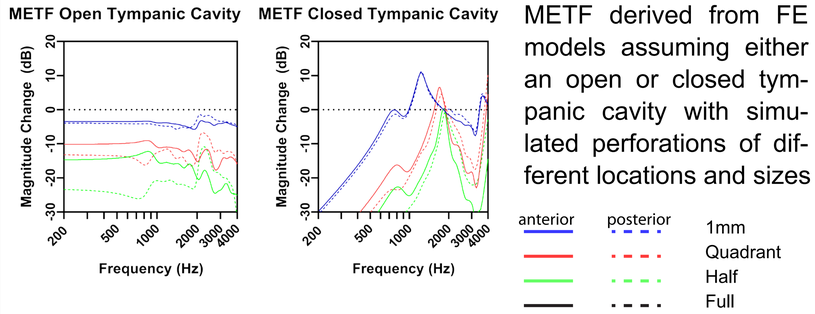


Magnitude changes between perforations, of different location and sizes, and control measurements. Solid line shows average, dotted lines individual temporal bones. The METF is reduced (except for anterior perforations of 1mm diameter) in amplitude with ever increasing damage to the TM. [4]

5: Finite-Elemente Model

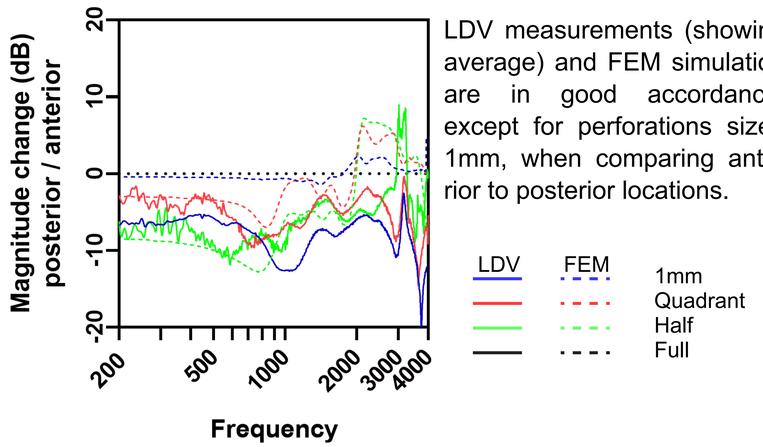


The FE model allows for selective removal of simulated polygons and thus testing of perforations at different locations and sizes. [3]



METF derived from FE models assuming either an open or closed tympanic cavity with simulated perforations of different locations and sizes

6: METF LDV compared to FEM simulation



LDV measurements (showing average) and FEM simulation are in good accordance, except for perforations sized 1mm, when comparing anterior to posterior locations.

Conclusion

Size and location of TM perforations have a characteristic influence on the METF.
The correlation of the experimental LDV measurements with an FE model contributes to a better understanding of the pathologic mechanisms of middle-ear diseases.

If small perforations with significant HL are observed in daily clinical practice, additional middle ear pathologies should be considered.
Further investigations on the loss of TM pretension due to perforations may be informative.

Literatur

[1] Traumatic Tympanic Membrane Perforations Diagnosed in Emergency Departments
Carniol et al. 2018

[2] Epidemiology and pathogenesis of chronic suppurative otitis media: implications for prevention and treatment.
Bluestone 1998

[3] Parameter Identification From Normal and Pathological Middle Ears Using a Tailored Parameter Identification Algorithm
Sackmann, Eberhard, Lauxmann 2022

[4] The impact of tympanic membrane perforations on middle ear transfer function
Bevis et al. 2022

Reviews

Evolution of Middle Ear Modelling Techniques: A Review
Parveen et al. 2021

Biomechanics of the tympanic membrane
Volandri et al. 2011