SUMMER STUDENT RESEARCH PROGRAM

PROJECT DESCRIPTION

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PROJECT TITLE (200 Characters max): Computational modeling of cholesteatoma using the finite element method

HYPOTHESIS:

Squamous epithelial migration (EM) of the tympanic membrane (TM) is a well-established phenomenon of normal ears, which likely represents a self-cleansing mechanism. Cholesteatoma is a non-cancerous disease where a sac of squamous epithelium from the TM invades the temporal bone and erodes bone, causing complications of hearing loss and vertigo. Surprisingly, most theories of cholesteatoma do not account for the native phenomenon of EM. We propose that initial retraction of the TM results from negative pressure in the middle ear, due to chronic Eustachian tube dysfunction. Focal retraction of the TM creates a retraction pocket, with an increasingly acute angle at the junction of the pocket with the bony ear canal. When the angle is sufficiently acute, epithelial migration becomes impeded. Over time, continued EM in a lateral direction within the retraction pocket results in redirection of the force vector into the middle ear, leading to inward buckling of the TM. We hypothesize that 1) this redirected force vector of EM explains the progression of retraction pockets into cholesteatoma sacs and 2) computer simulation with the finite element method (FEM) can be used to investigate whether the micromechanical forces of EM are sufficient to buckle the TM inward and potentially explain how cholesteatomas originate.

PROJECT DESCRIPTION (Include design, methodology, data collection, techniques, data analysis to be employed and evaluation and interpretation methodology)

This project will require close collaboration with Dr. Max Roman, an expert in the finite element method (FEM) at the New Jersey Institute of Technology. The first goal of the project will be to assemble a 3-dimensional “mesh” model of the human temporal bone, based on sections of an anonymized temporal bone specimen which we already possess. Using CAD software, the model will be rendered suitable for FEM simulation. Values gleaned from existing literature on FEM modeling of the TM and middle ear as well as from in vitro experiments demonstrating micromechanical forces of epithelial migration will be incorporated into the model. Computer simulations will be carried out using software such as MIMICS to determine if these micromechanical forces are sufficient to explain inward buckling of the TM. Systematic varying of a range of physical values (i.e. elasticity of the TM, magnitude of forces exerted by epithelial migration, middle ear pressure) will be performed to investigate the relative importance of these values for cholesteatoma formation.

SPONSOR’S MOST RECENT PUBLICATIONS RELEVANT TO THIS RESEARCH:
Summer Student Research Program
Project Description


IS THIS PROJECT SUPPORTED BY EXTRAMURAL FUNDS?
Yes ☐ or No ☒
(If Yes, please supply the granting agency's name)

THIS PROJECT IS: ☐ Clinical ☒ Laboratory (computational) ☐ Behavioral
☒ Other

THIS PROJECT IS CANCER-RELATED ☒ No
Please explain Cancer relevance

THIS PROJECT IS HEART, LUNG & BLOOD-RELATED ☒ No
Please explain Heart, Lung, Blood relevance

THIS PROJECT EMPLOYS RADIOISOTOPES ☒ No

THIS PROJECT INVOLVES THE USE OF ANIMALS ☒ No
Pending ☐ Approved ☐ IACUC Protocol #

THIS PROJECT INVOLVES THE USE OF HUMAN SUBJECTS ☒ No
Pending ☐ Approved ☐ IRB Protocol # M

THIS PROJECT IS SUITABLE FOR:
Undergraduate Students ☐ Entering Freshman ☒ Sophomores ☒ All Students ☒

THIS PROJECT IS WORK-STUDY: Yes ☐ or No ☒

THIS PROJECT WILL BE POSTED DURING ACADEMIC YEAR
WHAT WILL THE STUDENT LEARN FROM THIS EXPERIENCE?

I expect that Neel Sangal will have a very rich experience in learning about computational modeling of a very common and interesting disease of the temporal bone. He will learn about the intricate anatomy of the human eardrum and middle ear hearing mechanism and will gain an understanding of the physical properties of these structures. He will receive a thorough introduction to the field of finite element modeling and will see the value of applying engineering principles to complex biological systems. In addition, I believe that he will see and experience the value of interdisciplinary collaboration, between two very different types of investigators. Ultimately, I hope that these experiments will allow him to participate in what I believe can be a fundamental breakthrough in our understanding of this common but poorly understood disease. To my knowledge, this is an entirely original project that has never been attempted before. Finally, I hope that this experience will inspire him to continue a career in academic medicine and use his considerable abilities for the advancement of otolaryngology (or whatever discipline he chooses).