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Modeling middle ear pressure regulation

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Purpose: A compete description of middle pressure (ME) regulation requires the simultaneous analysis of gas transfers across all pathways that affect ME gas volume, the effect of those transfers on system volume and the effects of ME pressure on barrier morphology.

Methods: A set of geometrical models for the passive exchange barriers (tympanic membrane [TM], ME mucosa [MEM]) and a model of the Eustachian tube (ET) were integrated into a model of ME pressure regulation. ME pressure behavior was simulated for assumed preconditions.

Results: The model is shown in the Figure. Operationally, three low-level models describe pathway specific gas transfers. TransTM and transMEM are passive exchanges specified by barrier geometry and the physiochemical properties of the barrier and each gas. These models output a gas-specific conductance that defines the rate of gas exchange/unit gradient //blood perfusion. The transET pathway represents the ME-nasopharyngeal exchange of mixed gases during ET openings. That model is specified by the geometry and tissue properties of the ET and outputs opening and closing pressures and a gas transfer function. Because ME gas partial-pressures and total pressure determine driving gradients for the exchanges and these are continuous changed by the exchange processes, the extant gradients must be specified by integrating transfers across all paths for the preceding interval. This is done by a mid-level integrator that inputs transfer functions from the low-level models, registers and stores gas partial-pressures and outputs total pressure. A high level interpreter evaluates total ME pressure using an equation relevant to pathology and, if satisfied, prescribes changes in system geometry that are imposed on the low level models to yield a different set of conductance/transfer functions. These revised functions are then used by the integrator for calculation of ME pressure at later intervals.

Conclusions: Simulations using this model accurately predict ME pressure behavior for a variety of preconditions. Moreover, the model holds the advantage of describing the changes in system behavior associated with the evolution of pathology.