Effect of Resistance-Compliance Changes in Fluidic Systems

Vivian Y., M.D. 1,2  Ryan Dunn, B.S. 3  Paul Strykowski, Ph.D. 4  Rick Oddsland, M.D., Ph.D. 1,2
1 Department of Otolaryngology, University of Minnesota 2 Department of Otolaryngology, Hennepin County Medical Center, 3 University of Minnesota Medical School, Minneapolis, MN, 4 Department of Mechanical Engineering, University of Minnesota, Minneapolis, Minnesota

ABSTRACT

Problem Addressed: Changes in head position are well known to induce vertigo. A simple physical model has been proposed to establish the fundamental hydrodynamic relationship between changes in resistance or compliance of system to transiently affect the equilibrium. The Resistance-Compliance Product is known to be proportional to time to equilibrium. Prior work established the effect of changing resistance in one limb on membrane displacement. The current project proposed mirror image compensatory changes in resistance to maintain equilibrium, and change compliance in the system to demonstrate the principle that the Resistance-Compliance Product is proportional to time to equilibrium.

Methods and Measures: A tilting platform was used to mimic changes in head position. The platform supported two parallel systems that were in communication through a membrane. The platform rotated from a tilted position to a vertical position, allowing recording of pressure on both sides of the membrane. Gates on both sides allowed control of resistance to fluid flow. Two different compliance conditions could be tested.

Results: With open valves, there was no pressure differential between the two systems during platform rotation, and no displacement of the membrane for either high compliant or low compliant membranes. When resistance was increased on either side, there was an increase in time to equilibrium. A compensatory increase in resistance on the contra-lateral side reduce time to equilibrium to baseline. An increase in resistance had less of an effect if compliance was lower.

Conclusions: When resistance or compliance of one fluid system was increased, there was a proportional increase in the observed time to equilibrium. A compensatory change in resistance or compliance could reduce the observed time to equilibrium.

Clinical Significance: The Resistance-Compliance Product can be manipulated to compensate for injury or disease that can affect resistance or compliance of either the perilymphatic or endolymphatic systems. Understanding the mechanisms may lead to new methods of treatment.

RESULTS

Figure One. Schematic of Parallel Fluid Pathway (PPP) construct. The two systems have mirror image adjustable resistors and fluid manometers. The fluid manometers measure pressure as well as provide a compliant component. The membrane interface between the two systems can be replaced to change the resistance or compliance of the system. The fluid pathways are open to atmosphere, as are the manometers. The manometers are stationary, and the construct can be rotated on an axis about the lower transverse member.

Figure Two. Side view of the PPP Construct. The construct is tilted back 45 degrees, and allowed to receive a fluid displacement. The fluid manometers reflect the lower pressure near the base due to the lesser height of the fluid column. The construct is rotated to an upright position by a motor. As the construct rotates, pressure at the base will increase, and pressure at the top will decrease. Any differences in pressure between the right and left side will be seen as a difference in fluid levels in the manometers. The pressure differential will also deform the membrane interface (not shown here).

DISCUSSION

Examination of the effect of resistance-compliance changes in fluidic systems shows how vertigo may be caused to a transient disequilibrium in the endolymphatic and perilymphatic systems’ hydrodynamic pressure caused by rotation. Furthermore, the time to equilibrium is proportional to the Resistance-Compliance Product in each set of two systems. The intention is to demonstrate that resistance and compliance on the endolymphatic and perilymphatic systems could be manipulated to reduce time to equilibrium. While prolonging time to equilibrium may represent a possible pathological explanation for vertigo, reducing time to equilibrium would theoretically represent a potential treatment.

CONCLUSIONS

Brief periods of disequilibrium have been produced in this model of parallel fluid pathways with a change in position. Changing the resistance or compliance of one fluid system will affect the depth and duration of the disequilibrium. A given change in one limb can be compensated by changes in resistance or compliance of the other. Further examination of these changes with regard to inner ear function, are issues yet to be examined. Understanding the physical characteristics may lead to improved treatment of vertigo.