### MENIERE'S DISEASE AND INNER-EAR CIRCULATION: A COMPUTATIONAL STUDY

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## Meniere's disease: inner-ear disorder



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# There is evidence that Meniere's disease patients have extra-cranial venous outflow strictures



Alpini et al 2013, 2016 Bruno et al. 2014 Bavera et al. 2015 Tessari et al. 2017 Toro et al. 2017 Frau et al. 2019\*

**Courtesy of Dr N Agarwal MD** 

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#### The question is: in what way, if any, will the inner-ear circulation be altered?

### **Animal experiments (Friis and Qvortrup, 2007)** Obstruction of the vein of the vestibular aqueduct (VVA)



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Is this true in humans?

Here we present some theoretical, quantified evidence that innerear circulation is disrupted by extra cranial venous obstructions













Macrophage Neutrophil

Microvasculature

Mast cell







Pulmonary circulation







## Numbers count: our mathematical model



## **Partial differential equations**

Physical principles of conservation of mass and momentum give:

$$\begin{array}{lll} \partial_t A + \partial_x (uA) &= 0\\ \partial_t (Au) + \partial_x \left[ A \left( \hat{\alpha} u^2 + \frac{p - p_e}{\rho} \right) - \frac{K}{\rho} \int \phi(A) dA \right] &= s_M \end{array} \right\} \\ s_M = -Ru - \frac{A}{\rho} \partial_x p_e - \frac{1}{\rho} \partial_x K \int \phi(A) dA \\ \hline \mathbf{Unknowns} & \left( \begin{array}{c} A(x,t) & \text{cross-sectional area} \\ q(x,t) & \text{flow} \\ p(x,t) & \text{internal pressure} \end{array} \right) \\ \hline \mathbf{Tube \ law} & p(x,t) = p_e(x,t) + K(A_0(x),h_0(x),E(x))\phi(A,A_0) \\ \hline \phi(A,A_0) = \left[ \left( \frac{A}{A_0} \right)^m - \left( \frac{A}{A_0} \right)^n \right] \\ \hline \end{array}$$

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#### VALIDATION: comparison with MRI measurements Pressure and flow in transverse sinuses



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#### VALIDATION: comparison with MRI measurements Flow in head and neck veins



## VALIDATION: comparison with MRI measurements Arterial flow comparisons with data



vertebral arteries; ICA: Internal Carotid

Artery; MCA: Middle Cerebral Artery;

BA: Basilar Artery; VA: Vertebral Artery.

**Right.** Asc. Ao.: Ascending Aorta; Kidneys: sum of both Renal Arteries; Tho. Ao.: Thoracic Aorta; Abd. Ao.: Abdominal Aorta; Ext. II. A.: External Iliac Artery; Fem. A.: Femoral Artery.

## **Case study**



## RESULTS: Predicted mean pressures in HC and stenotic cases





#### **RESULTS**

#### **Predicted cerebrospinal fluid pressures**



### **Summary of our results**

- Inner-ear circulation is disrupted
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#### **ACTUALLY:**

The entire cerebral and spinal fluid dynamics is disrupted

## **Potential consequences of our results**

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- Locally, perfusion pressure is decreased
- Locally, clearance capacity of metabolic waste is reduced
- Perilymphatic pressure may be increased
- Endolymphatic pressure may be affected
- Potentially, rupture of membranes may occur
- Potassium intoxication

## Desirable extension of this work: endolymphatic and perilymphatic spaces



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## **Thank You**