Understanding the Mechanism of Retinal Displacement Following Surgical Management of Rhegmatogenous Retinal Detachment: A Computer Simulation Model

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Background

- There are several methods of repairing RRD including pneumatic retinopexy (PnR), silicone oil (SO), and gas pars plana vitrectomy (PPV)
- Retinal displacement, detected by the presence of retinal vessel printings on fundus autofluorescence imaging, is common following PPV (Fig 1)
- Retinal displacement remains a poorly understood phenomenon with unclear pathophysiology
- A recent study demonstrated that retinal displacement rates are significantly lower with PnR compared to PPV
- Although a variety of modifications to vitreoretinal surgical techniques have been suggested, there has been no definitive strategy that substantially minimizes the risk of retinal displacement
- The purpose of this study was to use a theoretical computer simulation model to assess the forces at play in retinal displacement
- Hypothesis: retinal displacement will result if the retina adheres to the retinal pigment epithelium (RPE) in a state of stretch or compression (Fig 2)

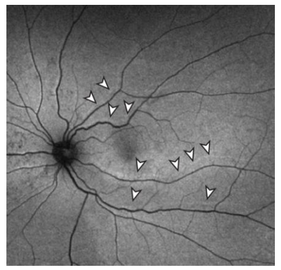

Fig 1. Retinal vessel printings on fundus autofluorescence Imaging. *Brosh et al 2020*

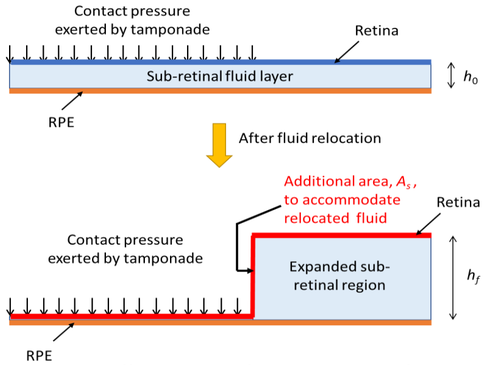

Fig 2. An illustration demonstrating how sub-retinal fluid displacement could lead to retinal stretching.

Methods

- To understand the mechanism of retinal displacement, we consider the interaction between the tamponade, vitreous, retina and subretinal fluid:
  - To determine the contact angle ($2\theta_c$), contact area (A_c), contact pressure (P_c), and the contact force (F_c) between the tamponade and the inner retina
  - To determine the dynamics of deformation of the retina and the displacement of subretinal fluid as a result of the contact pressure exerted by the tamponade on the inner retina
- All calculations are performed for an air tamponade in water as with PPV, an air tamponade in vitreous as in PnR, and SO in water

Methods cont.

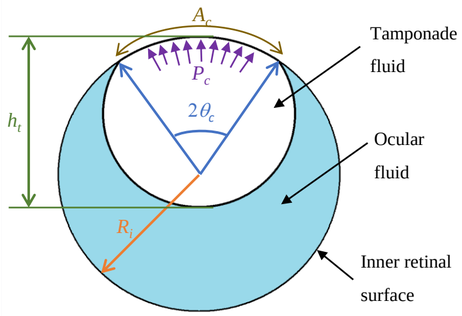

Fig 3. Definition sketch for the calculation of the contact angle, area, pressure and force corresponding to the interaction of the tamponade fluid with the ocular fluid

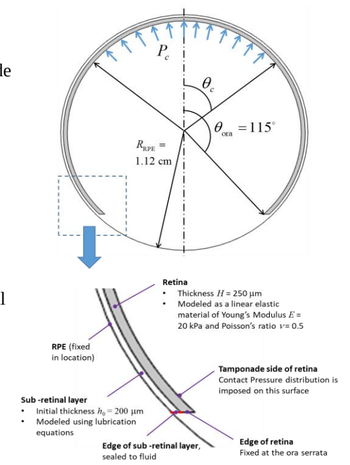

Fig 4. The geometry used in the simulations of the deformation of the retina and the flow in the sub-retinal space when a pressure P_c is imposed.

Results

- The Bond number (Bo) is a measure of the tamponade forces against the retina to deform it, and the interfacial tension forces attempting to maintain the spherical shape of the tamponade. It is defined as:

$$\mathrm{Bo} = \frac{\Delta \rho g a^2}{\gamma}$$

- Small Bo: tamponade nearly spherical, and will have a relatively small contact area (e.g. PnR and SO)
- Big Bo: the tamponade will be highly deformed with a nearly flat bottom, and will have a relatively large contact area (e.g. PPV)

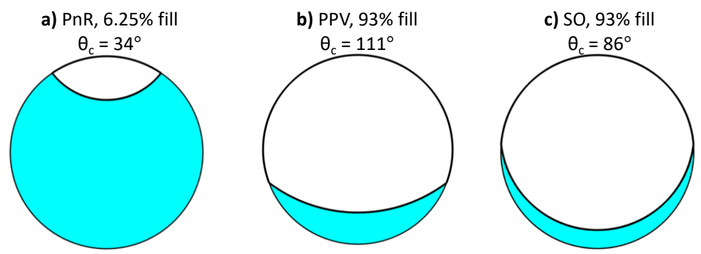

Fig 5. The shape of the tamponade for the cases of (a) PnR, (b) PPV, (c) SO. The white region in the shapes shown represent the tamponade, and the blue region represents ocular fluid phase.

Results cont.

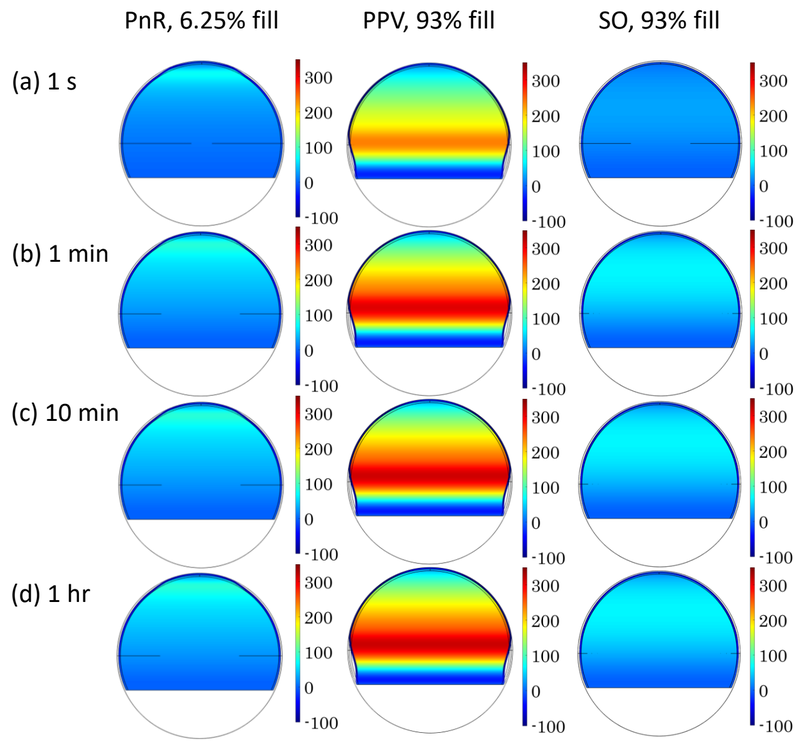

Fig 6. The retinal displacement profile, which is the component of the displacement field (µm) on the inner retina in the θ direction for PnR, PPV and SO at (a) 1 s, (b) 1 min, (c) 10 min, (d) 1 hr. The initial thickness of the subretinal film is 200 µm. Bottom of the images represent the anterior portion of the eye.

Conclusion

- The results of this study demonstrate that iatrogenic flow of subretinal fluid induced by the buoyant force of the endotamponade leads to retinal stretching and displacement
- Retinal stretch occurs less significantly with PnR and SO compared to PPV
- This model provides a framework with which variations in surgical technique can be simulated to determine how retinal displacement can be minimized
- Future studies will consider patient positioning following RRD repair surgery, a 3-dimensional model of fluid relocation, and the thickness of the subretinal fluid before endotamponade injection