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EFFECT OF INTRAOCULAR PRESSURE AND CEREBROSPINAL FLUID PRESSURE ON RETINAL HEMODYNAMICS

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The lamina cribrosa (LC) is a collagen structure in the optic nerve that helps maintaining the pressure difference between the intraocular pressure (IOP) inside the eye globe and the cerebrospinal fluid pressure (CSFp) in the retrobulbar region, while allowing the passage of retinal ganglion cells axons from the eye to the brain. Increased trans-lamina cribrosa pressure difference (TLpD) has been suggested as possible risk factor for glaucoma, which is the second leading cause of blindness worldwide [1]. An increase in TLpD is either due to IOP elevation or CSFp reduction. We developed a mathematical model to estimate, quantify and compare the influence of changes in IOP and CSFp on retinal hemodynamics.

The model incorporates a description of the LC deformation and blood flow in the retinal vasculature. The LC is modeled as a nonlinear, homogeneous, isotropic, elastic circular plate of finite thickness, which deforms under the combined action of IOP, CSFp and scleral tension. The blood flow in the central retinal artery and vein (CRA and CRV) is modeled as the Stokes flow of an incompressible Newtonian fluid filling a linearly elastic cylindrical shell. The walls of CRA and CRV deform under an external pressure that varies along the vessel length to include CSFp, IOP and the effect of LC deformation [2]. Retinal arterioles, capillaries and venules are modeled as a network of resistances. Flow rate (Q) and blood velocity in the pre-laminar segment of CRA and CRV (Va and Vv) are compared for:
case 1: IOP and CSFp that vary independently (**(1a)**: IOP $\in$ [15,50]mmHg, CSFp constant; **(1b)**: CSFp $\in$ [1,15]mmHg, IOP constant; **(1c)**: CSFp $\in$ [15,60]mmHg, IOP constant);
case 2: IOP and CSFp that may change with mean arterial blood pressure (MAP) (**(2a)**: MAP $\in$ [62.22,108.89]mmHg, CSFp=0.324MAP/7+8.6mmHg [3] and IOP constant; **(2b)**: MAP $\in$ [62.22,108.89]mmHg, CSFp=0.324MAP/7+8.6mmHg [3] and IOP=

0.243MAP/7+11.76mmHg [4]).
The baseline values are IOP=15mmHg, CSFp=7mmHg and MAP=93.33mmHg.
The model predicts that, for a given TLpD, IOP affects retinal hemodynamics more than CSFp, see Figure 1. For example, for |TLpD|=33mmHg (solid black line), when IOP=40mmHg and CSFp=7mmHg (case (1a) red curve) the flow rate Q is reduced of 38% from baseline, whereas for IOP=15mmHg and CSFp=48mmHg (case (1c) blue curve) Q is reduced of only 4% from baseline. Interestingly, flow rate reductions correspond to reductions in Va and Vv in the case (1a) and to increases in Va and Vv in the case (1c). The differences between the model predictions corresponding to cases (2a) and (2b) are minimal (less than 2%), see Figure 2.

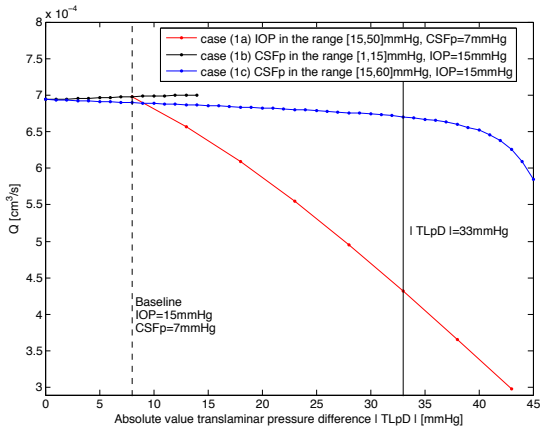

Figure 1

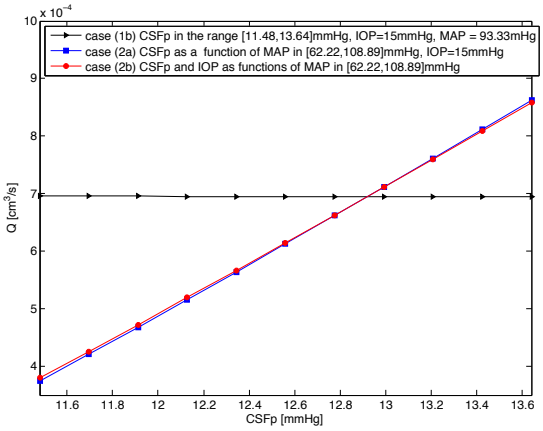

Figure 2

Changes in IOP have a stronger effect on retinal hemodynamics than changes in CSFp, even though these changes lead to the same TLpD. This might be due to the fact that, unlike CSFp, IOP acts directly on the intraocular retinal vessels, thereby altering the vascular resistance of the microcirculation. Our model also suggests that the CSFp influence on retinal hemodynamics might be mediated by associated changes in MAP.

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