A web-based interface for ocular hemodynamics and biomechanics analysis *via* the Ocular Mathematical Virtual Simulator

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Purpose

Optic neuropathies such as glaucoma are often late-onset, progressive and incurable diseases.

Principally, these disorders are caused by pathogenic hemodynamics and biomechanics in the back of the eye.

Data on ocular posterior tissues are difficult to estimate non-invasively and their clinical interpretation remains challenging due to the interaction among multiple factors that are not easily isolated.

We have developed a user-friendly web interface that employs the Ocular Mathematical Virtual Simulator (OMVS) to perform real-time simulations estimating ocular hemodynamical and biomechanical conditions based on patient-specific input data.

Methods

The OMVS (Fig. 1a) combines 1) a three-dimensional (3d) porous-media model for lamina cribrosa (LC) perfusion with 2) a circuit-based model for blood flow in retrobulbar and ocular posterior segments and 3) a 3d elastic model to simulate the biomechanics of LC, retina, choroid, sclera, and cornea.

Systems 1), 2) and 3) are solved using advanced computational methods (*Feel++*, *OpenModelica*) within a web simulation interface (Fig. 1c) that provides two applications: i) the OMVS View App (Fig. 1d), allowing the user to explore the simulation results that are stored in a private database, and ii) the OMVS Compare App (Fig. 1b), supporting a comparative analysis of multiple assessments of different patients or of the same patient at different visits.

Results

A virtual patient database (Fig. 2a) made of synthetic data inspired by the clinical literature was generated to test the web interface, which is used as a virtual laboratory for hemodynamical and biomechanical analysis.

Fig. 2b suggests that virtual patients with high intraocular pressure (IOP) have a decrease (up to 66%) in central retinal vessels blood flow; however this reduction is less marked in subjects suffering from high intracranial pressure (ICP) and/or high systolic/diastolic blood pressure (BP, Figs. 2c and 2d, up to 64% and 58%, respectively).

Conclusions

The OMVS web-interface provides an accessible environment where the user can isolate single risk factors and inspect their influence on the overall system.

The proposed interface may serve as a complementary method of data analysis and visualization for clinical and experimental research and a training application for educational purposes.

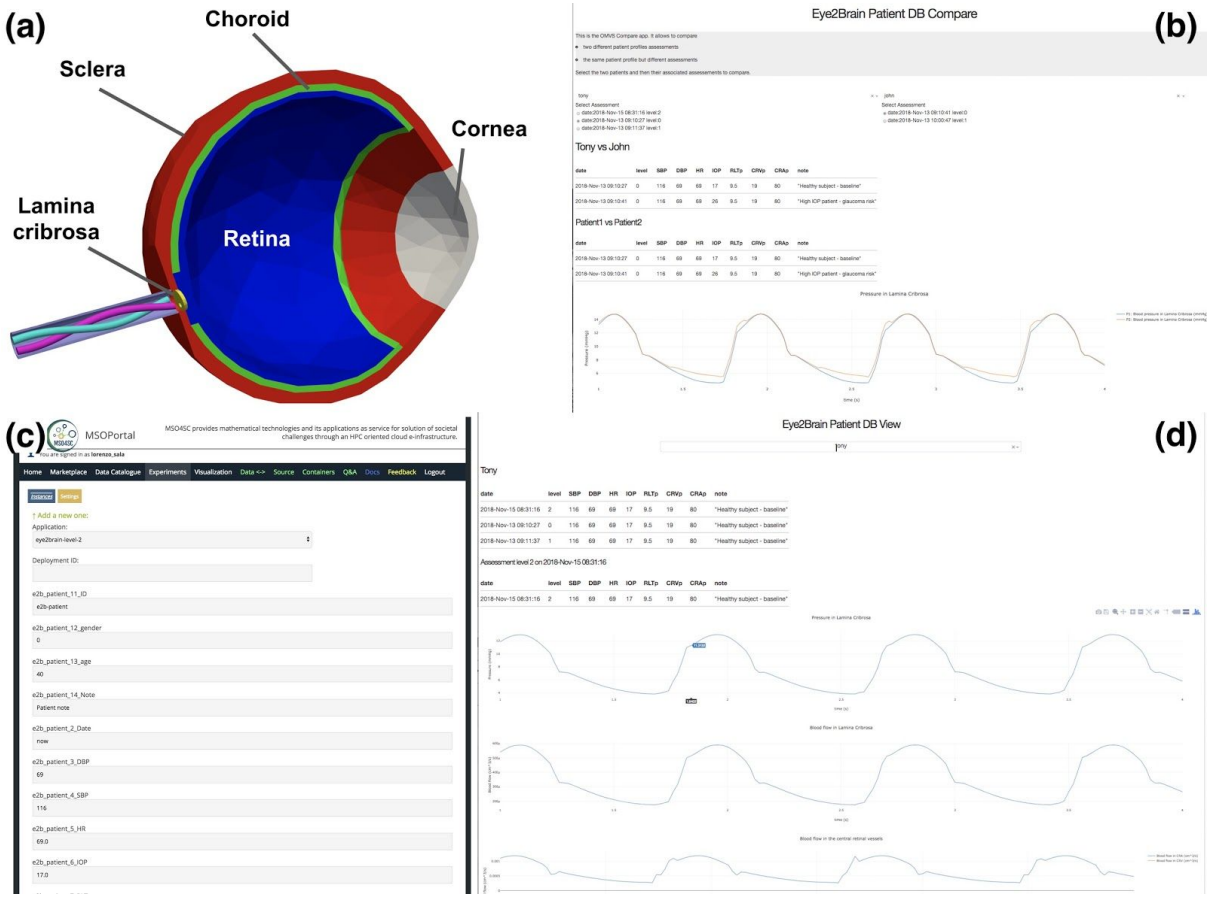

Fig 1: OMVS web tool overview

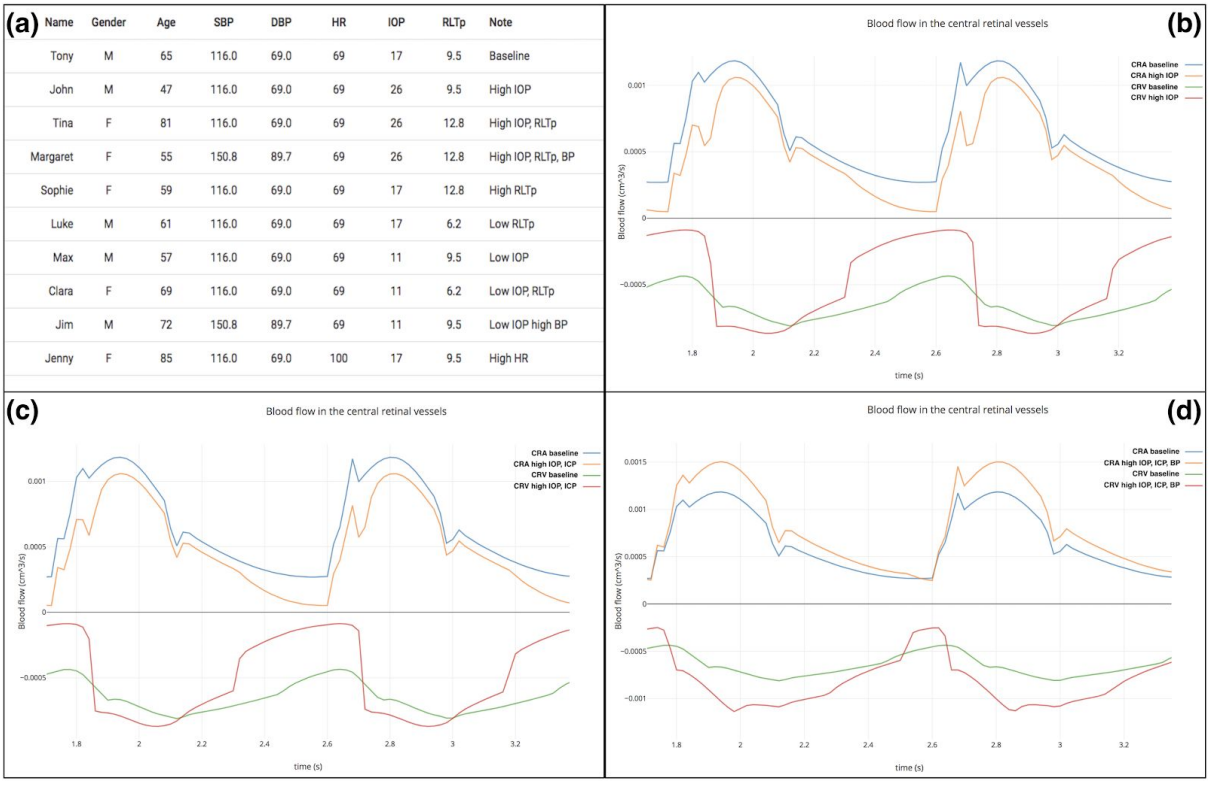

Fig. 2: OMVS database and simulation results varying IOP, ICP and BP

LAYMAN ABSTRACT:
Optic neuropathy can be caused by demyelination, inflammation, ischemia, infiltration, compression, and hereditary and toxic/nutritional causes.
The clinical evaluation is crucial in order to perform the correct diagnosis for each patient, however several different factors that are difficult to disentangle may affect experimental investigations.
Starting from clinical measurements (such as blood pressure, intraocular pressure, cerebrospinal fluid pressure), our proposed ocular mathematical model can simulate patient-specific situations and may predict unphysiological behaviors in a virtual environment.
Through the easy-to-use web interface, the user can exploit this online tool to perform innovative studies where single risk factors can be isolated and their influence on the overall system can be investigated.
In particular, hemodynamical and biomechanical three-dimensional virtual images are available to doctors for a more suitable diagnosis.