# PHYSIOLOGY-INFORMED MACHINE LEARNING FOR PATIENT-SPECIFIC INTRAOCULAR PRESSURE AND BLOOD PRESSURE MANAGEMENT IN GLAUCOMA

Lorena Bociu
*Mathematics, North Carolina State University, Raleigh, NC, United States*

Giovanna Guidoboni
*Electrical and Computer Engineering, University of Maine, Orono, ME, United States*

Alon Harris *and* Brent Siesky
*Ophthalmology, Icahn School of Medicine at Mount Sinai, New York, NY, United States*

Daniele Prada
*CNR–IMATI, Pavia, Italy*
*e-mail: daniele.prada@imati.cnr.it*

Riccardo Sacco
*Mathematics, Politecnico di Milano, Milano, Italy*

Vision loss in many glaucoma patients continues despite successful treatment aimed at lowering intraocular pressure. The reasons why this happens remain elusive. Here, we show that mathematical modeling and machine learning can help identify subgroups of glaucoma patients whose disease process entails different relative contributions of risk factors, particularly intraocular pressure and blood pressure. This work may enable the development of novel precision medical approaches for glaucoma care.

**Keywords**: *physiology-informed machine learning, glaucoma, mathematical modeling, patient-specific, precision medicine*

## 1. Purpose

Vision loss in many open-angle glaucoma (OAG) patients continues despite successful treatment lowering intraocular pressure (IOP). The reasons remain elusive. Here, we show that mathematical modeling and machine learning (ML) can help identify subgroups of OAG patients whose disease process entails different relative contributions of IOP and blood pressure (BP).

## 2. Methods

115 OAG patients were assessed every 6 months over a 7-year period for IOP, systolic and diastolic blood pressures (SBP, DBP), heart rate (HR), structural and hemodynamic evaluations via ocular coherence tomography (OCT), Heidelberg Retinal Tomography (HRT), Heidelberg Retinal Flowmetry (HRF), and Color Doppler Imaging (CDI). Fuzzy c-means (FCM) clustering was applied to the dataset comprising: (i) IOP, SBP, DBP, HR measured at the first visit for each patient in the IGPS study; and (ii) patient-specific estimates of vascular pressures and resistances, mechanical stresses and strains, obtained via validated mathematical models [1, 2]. FCM is part of ML and the mathematical models are based on physiology, leading to physiology-informed ML. Follow-up visits and data from OCT, HRT, HRF and CDI were not used for clustering.

## 3. Results

While the data for IOP and mean arterial pressure (MAP) for the first visit of each IGPS patient do not exhibit any particular pattern, the physiology-informed ML method revealed distinct clusters, which are associated with different clinical outcomes after 4 years (p values obtained with the 2-sample paired Wilcoxon signed rank test for medians). Clusters show minimal glaucoma progression, marked structural progression accompanied by significant hemodynamic changes and/or significant changes only in HRT and HRF markers, but not in OCT and CDI.

## 4. Conclusions

This study suggests that the proposed physiology-informed ML approach can identify and quantify the relative contributions of IOP and BP on the OAG risk for patient subgroups. Thus, this approach may enable precision medical approaches of IOP and BP management in OAG.

## REFERENCES


1. Guidoboni, G., Harris, A., Cassani, S., Arciero, J., Siesky, B., Amireskandari, A., Tobe, L., Egan, P., Januleviciene, I. and Park, J. Intraocular pressure, blood pressure, and retinal blood flow autoregulation: A mathematical model to clarify their relationship and clinical relevance, *IOVS*, **55**, 4105–4118, (2014).

2. Causin, P., Guidoboni, G., Harris, A., Prada, D., Sacco, R. and Terragni, S. A poroelastic model for the perfusion of the lamina cribrosa in the optic nerve head, *Mathematical Biosciences*, **257**, 33–41, (2014).