# EYES ON BIG DATA

## Infrastructure, AI, and the role of eye care in the future of health care.

BY DAVID C. RHEW, MD

The term *oculomics*—the science of using fundus photographs or other ocular data to identify disease, detect biomarkers, and generate health-related predictions—was coined in 2020.[1] The concept that systemic disease can be identified through ocular findings, however, has been recognized by the scientific community for more than a century. Though research using AI to analyze retinal images to provide insights into systemic health exploded in recent years, real-world adoption is still in the early stages. This is largely because implementing oculomics in clinical practice requires the following:

- Large, well-curated datasets;
- Efficient AI model development and validation;
- Clinical workflows that translate insights into action; and
- A connected care network to route patients appropriately.[2]

This infrastructure is essential to ensuring that patients receive the right care at the right time. *(Editor's note: See* Organizations and Initiatives Building Oculomics Infrastructure *for a list of select groups building the standards and real-world pathways needed to scale oculomics.)*

Key challenges include data management, AI model training and testing, and ensuring safe, secure collaboration across stakeholders.

## LAYING A FOUNDATION: BIG DATA AND AI TRAINING

### Why Existing Data Fall Short

Although datasets currently exist, many are siloed or based on images of inadequate quality. These limitations impede the identification of clinically relevant features and the ability to train AI models efficiently.

Data curation and annotation, interoperability, and the development of standards that enable data exchange across systems are therefore critical priorities.

### Training Models That Generalize

Once high-quality datasets are available, models must be built to support generalizability and mitigate bias where it exists. Rigorous testing is also required to confirm model quality, accuracy, and reliability.

### Moving Beyond Manual Labeling

Traditionally—and laboriously—foundation models have been developed by having humans read and label images one by one. Looking ahead, large, unlabeled datasets of normal images may serve as comparison baselines from which AI models can learn. One example is RETFound, a foundation model for retinal imaging that was pretrained on 1.6 million unlabeled retinal images using self-supervised learning.[3] Self-supervised learning can reduce both time and cost, and it may help accelerate innovation.

## CREATING PATHWAYS: SECURE COLLABORATION

### Why Centralized Datasets Are Hard to Create

Creating a large, centralized dataset may seem like the simplest way to facilitate collaboration, but privacy, security, and liability concerns make this approach difficult. For example, if researchers in different countries wanted to combine two valuable datasets, government regulations, institutional policies, or even personal preferences might prevent those researchers from transferring data to a central repository. Even if data aggregation were possible, questions remain. Who would own the combined dataset, and who would be responsible in the event of a breach? How could sites collaborate if they could not—or chose not to—share data?

A few proven approaches can help address these barriers.

### Deidentification Mechanisms

Deidentification mechanisms can remove certain patient identifiers to protect patient privacy.

### Federated Learning

Federated learning—bringing AI models to the data—allows datasets to remain at their originating sites instead of requiring their migration or copying to a centralized location. When standards are established to ensure that each site applies models in the same way, federated learning can enable collaboration without exchanging data.

### Hardware-Enforced Encryption

Another approach involves privacy-preserving technologies in which data and AI models are moved into a secure enclave (the microchip itself). AI is applied to datasets without exposing either the data or the model. This hardware-enforced encryption can prevent unauthorized access to both the underlying data and the AI models.

## REAL-WORLD CHALLENGES: REFINING THE PATIENT PIPELINE

### The Bottleneck Is Not Detection

Applying oculomics and AI to identify disease is one thing. Ensuring that newly diagnosed patients receive timely care in an environment where clinicians are already overextended and resources are limited is another.

This tension became clear during a project in East Texas that deployed AI screening for diabetic retinopathy in a primary care setting. Among the first 50 patients imaged, 20% had moderate to severe diabetic retinopathy requiring evaluation or treatment, which created a surge of referrals for an already busy ophthalmology service.[2]

### A Workflow Model That Scales

A California-based integrated delivery network has implemented an effective model to operationalize the process.[4] Rather than refer every patient with diabetes to an ophthalmologist, the network uses a reading center to perform risk stratification screening. In this setting, high-risk patients are directed to eye care practitioners for procedures, whereas medium- and low-risk, or stable, patients are managed by the reading center. Eye care caseloads remain steady, specialists see a higher-acuity population, and fewer medium- and low-risk patients are referred for routine follow-up visits. This approach allows each member of the eye care team to practice at the top of their license while supporting more timely care for the patients who need it most.

## FUTURE DIRECTIONS

The examples provided in this article represent only the beginning of what may become a broader transformation of health care.

Although many aspects of care might be improved with AI and related technologies, further validation is required to ensure that these approaches enhance patient outcomes, support appropriate resource allocation, and perform well across diverse settings.

In the future, tighter alignment between primary care and specialty care might help streamline patient

## AT A GLANCE

- Oculomics leverages fundus photographs and other ocular data–often analyzed with AI–to identify systemic disease signals, detect ocular-derived biomarkers, and generate risk predictions beyond eye care.
- Real-world adoption of oculomics is in the early stages, with limited large-scale clinical deployment to date due to a lack of robust infrastructure.
- Scaling oculomics depends on building interoperable, high-quality datasets; developing more generalizable and less biased AI (including self-supervised foundation models); and implementing privacy-preserving, workflow-ready systems that translate predictions into risk-stratified referrals and connected care pathways.

## ORGANIZATIONS AND INITIATIVES BUILDING OCULOMICS INFRASTRUCTURE

BY MICHELE CORRY, EDITOR-IN-CHIEF

Following are some of the groups that are advancing data standards, validation pathways, and implementation frameworks for oculomics.

The Alliance for Healthcare from the Eye is a multisector consortium of health systems, clinicians, researchers, payors, policymakers, regulators, data privacy experts, and industry leaders. It provides a structured approach to identifying barriers to real-world implementation and defining calls to action to advance clinical, regulatory, operational, and ethical standards.[1]

Working in partnership with the Alliance for Healthcare from the Eye, the Collaborative Community on Ophthalmic Innovation is developing practical frameworks to support the safe, effective, and scalable adoption of oculomics. Priorities include image-acquisition quality criteria, reference endpoints for accurate assessment, and sustainable reimbursement models.[2]

Additional initiatives contributing to the oculomics ecosystem include the following:

- Institute for Digital Health, part of Topcon Healthcare's Healthcare from the Eye initiative (idhea.net/en)[3];
- Insight Health Data Research Hub for Eye Health and Oculomics[4];
- National Institutes of Health Common Fund Venture Program Oculomics Initiative[5]; and
- UK Biobank: Oculomics Research Efforts.[6]

1. Alliance for Healthcare from the Eye. The Alliance for Healthcare from the Eye launches to transform disease detection and coordinated care delivery with oculomics and artificial intelligence (AI) [press release]. May 13, 2025. Accessed January 1, 2026. https://www.healthcarefromtheeye.org/wp-content/uploads/2025/05/AHE_PressRelease_5-13-25.pdf
2. Collaborative Community on Ophthalmic Innovation Foundation. Collaborative Community on Ophthalmic Innovation (CCOI). Accessed January 1, 2026. https://cc-oi.org
3. Weinreb RN, Lee AY, Baxter SL, et al. Application of artificial intelligence to deliver healthcare from the eye. *JAMA Ophthalmol*. 2025;143(6):529-535.
4. INSIGHT Health Data Research Hub for Eye Health. Oculomics. INSIGHT. Accessed January 1, 2026. https://www.insight.hdrhub.org/oculomics
5. National Institutes of Health. Common Fund Venture Program: Oculomics. Accessed January 1, 2026. https://commonfund.nih.gov/venture/oculomics
6. UK Biobank. A multi-omics perspective on eye disease prediction. Accessed January 1, 2026. https://www.ukbiobank.ac.uk/projects/a-multi-omics-perspective-on-eye-disease-prediction/

flow, and AI could play a central role in directing patients to the right level of care. Retail clinics, pharmacies, and other organizations might also help expand capacity and reduce costs by leveraging AI as a screening or prescreening tool.

### EYE CARE'S OPPORTUNITY

Oculomics creates unprecedented opportunities to build a more effective health care system and for eye care providers to take a leading role in preventive care beyond ocular disease. In the future, eye care providers may help track biomarkers of neurodegenerative conditions such as Alzheimer disease, multiple sclerosis, and Parkinson disease. They may also play a greater role in identifying and managing patients with acute, subacute, and chronic disease, including diabetes, cardiovascular disease, chronic kidney disease, hypertensive retinopathy, and even preeclampsia—making eye care a more integral part of whole-person health. ■

1. Wagner SK, Fu DJ, Faes L, et al. Insights into systemic disease through retinal imaging-based oculomics. *Transl Vis Sci Technol*. 2020;(2):6. Erratum in: *Transl Vis Sci Technol*. 2021;10(8):13.
2. Weinreb RN, Lee AY, Baxter SL, et al. Application of artificial intelligence to deliver healthcare from the eye. *JAMA Ophthalmol*. 2025;143(6):529-535.
3. Zhou Y, Chia MA, Wagner SK, et al. A foundation model for generalizable disease detection from retinal images. *Nature*. 2023;622(7981):156-163.
4. Tarasewicz D, Karter AJ, Pimentel N, et al. Development and validation of a diabetic retinopathy risk stratification algorithm. *Diabetes Care*. 2023;46(5):1068-1075.

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