Ophthalmology's new horizon: Moving from reactive care to proactive artificial intelligence solutions

Artificial intelligence (AI) is the next revolution in health care, poised to usher in monumental improvements in patient care. We will transition from reactive medicine to one that is proactive and preventive. This paradigm shift is especially urgent in ophthalmology, where we experience an escalating burden of chronic conditions. This special issue underscores our commitment to harnessing AI's transformative potential, presenting readers with a mix of review articles and original research. Central to our exploration is the introduction to foundation models and vision transformers, the latest progress in deep learning. We delve into ophthalmology's distinctive vantage point, termed "oculomics," which finds a growing number of systemic conditions through the direct visualization of the eye, from predicting heart attacks to detecting Parkinson's disease before clinical symptoms. We delve into the potential of AI for corneal and ocular surface disease, with a focused review complemented by original research. This section not only illuminates the advances in this specific domain but also showcases how the democratization of AI is being realized through code-free tools like autoML, making sophisticated AI techniques accessible to a broader audience.

Historically, ophthalmological computer vision models have predominantly relied on Convolutional Neural Networks (CNNs), a specialized subset of deep neural networks tailored for analyzing visual images. Typically, CNNs are used for supervised learning, which involves training the model using labeled data. The landscape, however, is rapidly evolving toward foundation models. Unlike CNNs, these models are pretrained on vast amounts of unlabeled data, harnessing broad data patterns through self-supervised learning (SSL). Serving as a foundation, they can then be fine-tuned for specific tasks with minimal additional data. This SSL paradigm represents a pivotal shift for medical research, offering an efficient alternative to labor-intensive, costly, and time-consuming process of data labeling intrinsic to supervised learning in CNNs.

The potential to train foundation models using diverse medical data, such as medical notes, lab results, genomics, imaging, and wearables, is promising. These wide range of data are more representative of the complex human condition, similar to how clinicians interact with multi-modal data. Thus, foundation models bring us a step closer to creating AI that processes information in a manner akin to humans.[1,2]

Transformers are a deep learning architecture that forms foundation models. Notably, transformers underlie advanced language models such as ChatGPT. For image data processing, visual transformers (ViTs) are a promising advancement.[3] Wu *et al*. provide an exploration of vision transformers in the realm of ophthalmology, emphasizing their adaptability in processing varied image sizes.[4] Their insights suggest that when paired with CNNs, ViT models can surpass the capabilities of standalone alternatives.

In the domain of Oculomics, the evolution and potential of the field are underpinned by a pivotal trifecta: The advent and availability of high-resolution optical coherence tomography (OCT) imaging, offering unprecedented insights into the microvasculature and central nervous system; the collation of previously siloed data, bridging the gaps between diverse datasets; and the power of AI, adept at analyzing and making sense of this reservoir of information. Highlighted in this edition are the myriad systemic diseases detectable through ocular examinations.[5] The potential implications of identifying systemic diseases through noninvasive and efficient methods are immense. A case in point is a recent study suggesting the early detection of Parkinson's disease through specific retinal indicators, well before its clinical onset.[6] As touched upon earlier, foundation models, with their adaptability, can be fine-tuned to diverse tasks. Recently, foundation models have emerged in ophthalmic research, with the SSL-based RETFound model being trained on an extensive collection of unlabeled retinal images. RETFound can diagnose and predict ocular and systemic diseases with minimal labeled data for fine tuning.[7]

In their comprehensive review, Pagano *et al*. spotlight the vast potential of AI in the realm of corneal and ocular surface disease.[8] Intriguingly, AI has shown to be better than clinicians at discerning between bacterial and fungal keratitis. For conditions like keratoconus, where early detection and intervention are paramount to prevent complications, AI's capability to identify nuanced changes in topographical images is invaluable. Mirroring the rich data landscape of OCT, which AI is utilized for disease segmentation, detection and prediction, anterior segment-OCT is poised to be the next frontier. Given the visual nature of many ocular surface diseases, the increased use of photographs could pave the way for a more integrated, AI-enhanced teleophthalmology service.[9]

Two review articles in this issue delve into the potential of code-free deep learning, or AutoML. These pieces showcase the ability for clinicians with no coding experience, to deploy AI applications. One article demonstrates the application of AutoML in detecting graft failure postkeratoplasty.[10] Another

highlights its efficacy in trachoma detection.[11] Notably, the trachoma detection algorithm created with autoML outperformed an algorithm created by AI experts for the same dataset. A significant feature of both these AutoML applications is their ability to operate offline, emphasizing their adaptability and versatility in various settings.

As the articles in this issue highlight, the democratization of AI, particularly evident with the surge in AutoML, is challenging the preconception that AI remains the exclusive domain of tech giants and specialized institutions. Companies such as Google, Apple, Facebook, and Amazon are now offering code-free AI tools and making AutoML platforms and foundation models available to a wider audience. The expansive potential applications and implications of these tools, especially in ophthalmology, are exciting. In a world where developing nations face a disproportionate burden from preventable vision loss and blindness, the increasing accessibility of AI tools like AutoML and foundation models can be revolutionary. As AI continues to democratize, there is an optimism that these innovative advancements will be leveraged to cater to underserved communities worldwide, paving the way for a more equitable and universally accessible vision care paradigm.

As we reflect on the insights presented in this issue, it is evident that AI will redefine healthcare, with ophthalmology being a key player. This issue presents the diverse capabilities of AI, from diagnosing systemic diseases using "oculomics" to advancements in novel techniques like foundation models. Their ability to process a broad array of medical data, much like clinicians, brings us closer to AI that mirrors human expertise. The next exciting phase is the transition from code to clinic, realizing AI's potential in the real world settings. Tools such as AutoML are democratizing AI, setting the stage for a health-care system that's more integrated and proactive. As we navigate this transformative journey, it is crucial to ensure the ethical, responsible adoption of AI, always prioritizing patient outcomes.

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