Artificial intelligence and oculomics: Improving global health

BY CHARLES CLELAND AND ELLIOTT TAYLOR

The application of artificial intelligence (AI), and in particular deep learning, to high-resolution ocular imaging has led to many new discoveries, enabling the prediction of multiple different systemic diseases from ocular biomarkers. This emerging field is known as 'oculomics' [1]. From AI analysis of non-invasive ocular imaging, there is increasing evidence that cardiovascular disease, diabetes, renal disease and neurodegenerative disease [2-5] can be detected, and even evidence that incident disease can be predicted several years before symptom onset [6].

This could fundamentally shift the way healthcare is delivered and potentially contribute to earlier, more accurate, more accessible and personalised diagnostics for multiple systemic diseases, enabling the earlier initiation of preventative interventions thereby reducing morbidity and mortality. The potential for these technologies to improve human health is arguably greater in low- and middle-income countries (LMICs) where healthcare infrastructure is more limited.

Healthcare challenges in LMICs

Low- and middle-income countries face many different healthcare challenges, but three are particularly pertinent when considering the potential value of oculomics:

1. A shortage of medical professionals
2. Limited access to specialist diagnostics
3. An increasing burden of non-communicable diseases (NCDs).

The result of these challenges is that people living in LMICs are often undiagnosed with NCDs such as diabetes or hypertension. For example, over 50% of people living with diabetes in sub-Saharan Africa are unaware they have the condition [7]. This means that people typically present late to medical services once they have already developed complications. Therefore, earlier diagnosis enabled by AI analysis of non-invasive ocular imaging has a particular application in low-resource settings.

Currently the majority of oculomics research concerns the prediction of NCDs

from ocular biomarkers. Of the 43 million people who die annually from NCDs, 73% live in LMICs. Cardiovascular diseases, which AI analysis of ocular imaging has shown particular promise at predicting, are responsible for the most NCD deaths (19 million annually) [8].

Opportunities for oculomics in LMICs

Integrating oculomics-based diagnostics into clinical pathways could provide an innovative, non-invasive and scalable solution to enable earlier diagnoses and improve health outcomes. If patients could be diagnosed earlier with diabetes or hypertension, for example, treatments could be started which delay or prevent complications. This could reduce the number of people who have strokes or who require dialysis for renal failure.

Retinal imaging is non-invasive, safe and cheaper than conventional blood tests which require laboratories, reagents and laboratory staff, making it a potentially cost-effective solution. This is particularly true if progression to renal failure and other complications is delayed or prevented, as downstream morbidity and need for medical treatment can be reduced. Moreover, it is rapidly scalable in a way that laboratory diagnostics are not. Oculomics-based AI diagnostics using ocular imaging do not require large capital investment in buildings and training of specialist staff. This could therefore rapidly improve access to diagnostics for underserved populations.

Challenges in implementing oculomics in LMICs

However, there are several challenges to implementing oculomics based diagnostics in LMICs. First, there is an underrepresentation of training data from populations living in LMICs used to train AI models. This means there are concerns about how accurate AI devices will be in underrepresented LMIC populations; this has been coined 'health data poverty' [9]. If not addressed, this issue could widen global health inequities.

Second, there are limited prospective studies evaluating oculomics-based tools in 'real world' programmes and very little clinical research evaluating whether they actually improve outcomes for patients.

Third, for any of these tools to be used at scale, they will need regulatory approval which generally requires commercialisation. For any AI devices that are commercialised there will be licence fee payments for use of the device, which may prohibit use in LMICs dependent on cost. Moreover, although AI analysis of retinal imaging is generally cheaper than many traditional diagnostics, it does still require up-front investment in fundus cameras, which typically cost >£20,000. This coupled with licence fee payments may make the solutions unaffordable for some countries.

Fourth, in some LMICs, and particularly in more rural regions, there is poor internet connectivity. Many healthcare AI devices are cloud-based therefore requiring good internet connectivity making them

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impractical for regions with poor internet access.

Fifth, and critically, better diagnostics does not mean better health outcomes for patients. It is essential that good-quality treatments are accessible for persons after diagnosis. If access to treatments is poor, patient outcomes will be poor.

Future work

To address these challenges and to contribute towards improved health outcomes for populations in LMICs using oculomics the following are needed. High quality and well curated datasets of ocular imaging and clinical data from underrepresented LMIC populations to ensure equitable development and validation of oculomics based AI devices. Prospective studies evaluating accuracy of AI devices in 'real-world' programmes and their impact on important measurable clinical outcomes. These should be coupled with economic evaluations to determine cost-effectiveness.

The quality of handheld fundus cameras is increasing rapidly; these are cheaper than traditional fundus cameras. If handheld cameras can provide sufficient image resolution to enable accurate oculomics-based AI analyses, they would provide a more cost-effective and scalable solution. Further research evaluating their potential role is needed, along with offline functionality to make solutions more practical.

Critically improved diagnostics need to be coupled with improved access to treatments. It would be neither effective nor ethical for improved diagnostics to be implemented without the availability of accessible, affordable and effective treatments.

Conclusion

Oculomics offers a potentially transformative opportunity to provide a scalable solution to rapidly increase access to high-quality diagnostics across a range of systemic conditions which are leading causes of death globally. This has the potential to address workforce challenges, limited access to traditional diagnostics and late presentations all of which contribute to poor health outcomes in LMICs. However, further work is needed to better represent LMIC populations in training and validation data for AI devices, along with prospective clinical trials to evaluate the impact of oculomics based AI solutions on clinical outcomes and improved access to effective treatments. These will all be needed before oculomics based AI solutions can be implemented and scaled to improve global health.

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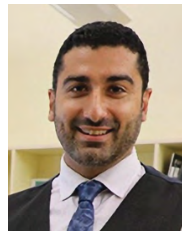

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