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Integrating artificial intelligence in ophthalmology: a pilot study of clinical understanding and adoption

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Abstract

Purpose: The purpose of this pilot study was to explore the current understanding and application of artificial intelligence (AI) within clinical ophthalmology.
Design: This study used a qualitative research approach. One-on-one interviews were conducted with ophthalmologists (including residents/fellows/students) and medical professionals involved in ophthalmology.
Methods: Participants were recruited via professional networks, and an interview guide informed by prior research and expertise of the interdisciplinary research team led the question-asking process. Transcribed interviews were analyzed using qualitative thematic analysis methods with Nvivo12 software.
Results: Participants (N = 18) included attending clinicians (44%, n = 8), residents (44%, n = 8), a fellow (6%, n = 1), and a medical student (6%, n = 1). In-depth analysis of the interviews yielded 3 overarching themes: 1) AI has high utility in ophthalmology; 2) AI is a tool, but a balance between AI and the clinician is important; and 3) several challenges to integrating and accessing AI need to be addressed. Overall, participants believed an AI informed clinical practice is important and participants

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described ways AI could be incorporated into their own patient management. However, the majority of participants do not presently use AI in patient care, noting concerns about the current state of AI in research and clinical practice. Participants also described balance between AI and the provider as essential, suggesting AI applications are not currently able to replace the human element of clinical practice. AI applications in ophthalmic clinical practice are viewed positively across all participants, with noted caution towards the current ability to use AI as an automated tool and challenges for its integration into clinical management. *Conclusions and future perspectives*: Although findings yielded generally favorable views, suggesting high potential for benefit with integration of AI systems, several barriers to adoption were noted by participants. While participants believe AI is the future of ophthalmology, a balance between the clinician and the computer is vital and concerns related to trustworthiness of the data were a consistent finding. This research lays important groundwork for developing future research that can bridge the gap between the development of AI systems and its translation to more effective clinical practice.

Keywords: artificial intelligence, clinical translation, computational intelligence, ophthalmology

Background

Artificial intelligence (AI) refers to the ability of a computer to autonomously accomplish tasks that involve elements of learning, reasoning, and problem-solving. Often used interchangeably with terms such as machine learning (ML) and deep learning, AI is a more encompassing term describing all programs with the ability to simulate intelligent thought processes similar to humans with minimal human involvement.[1] As AI has evolved, its use and application has similarly progressed, including in the field of medicine. Broadly, AI has been applied to many facets of medical care, from patient screening and diagnosis to treatment and management decision-making.[1] Today, AI is being applied to our most important issues, including the COVID-19 pandemic to evaluate epidemiologic trends and to explore the creation and use of novel medications and vaccines, among other applications.[2]

Historically, ophthalmology has been on the forefront of AI investment and research due to its heavy use of digital imagery and difficulty in direct assessment of diseased tissue. Specifically, AI has been applied to conditions including diabetic retinopathy, retinopathy of prematurity, macular edema, age-related macular degeneration, and glaucoma to enhance clinician ability to diagnose, monitor progression, and treat these conditions.[3] In glaucoma, AI methods have been used to aid disease diagnosis and monitoring.[4] AI systems have been trained to diagnose glaucoma based on fundus photography,[5] to evaluate disease progression based on visual field patterns and ocular coherence tomography,[6,7] and to reveal the influence of hemodynamic alterations on disease, shifting the paradigm of glaucoma screening and disease management.[8]

Although research into the application of AI to ophthalmology is broad, direct clinical use and translation of AI technology is not routine. While data has shown that clinical ophthalmologists are twice as likely to use AI in daily practice when compared to other clinicians, less than 20% of ophthalmologists are currently using AI to aid in clinical practice.[9] Given the potential for widespread application of AI technology in ophthalmic practice, this study aimed to explore the current understanding and application of AI through one-on-one interviews with medical professionals of clinical ophthalmology. With this research, we will use findings to inform attempts at expanding the clinical application of AI in ophthalmology with implications for many other medical disciplines.

Methods

This exploratory pilot study utilized one-on-one interviews with medical professionals in ophthalmology, including residents, fellows, attending clinicians, and other professionals involved in the diagnosis and treatment of eye disease. The study team consisted of interdisciplinary researchers and practitioners with experience in AI research, representing the fields of engineering, mathematics, ophthalmology, and the social sciences. The lead author has a background in social science and public health research, as well as qualitative methodologies. While this expertise informed the study design and data collection methodologies, it may have also introduced potential for bias, particularly since the lead author is not a trained ophthalmologist. This could have affected the framing of follow-up questions during the interviews and interpretation of responses. Efforts to mitigate this included peer debriefing within the interdisciplinary team, which provided alternative perspectives and helped contextualize the findings within clinical practice.

As this study used a qualitative design, a small sample with a relatively homogeneous group of participants with a narrowly defined area of study was appropriate, particularly given that this study was exploratory in nature and used as a pilot for additional research.[10,11] Therefore, we aimed to recruit 15–20 participants to complete an in-depth interview. Recruitment ended when the researchers felt that saturation had been reached, which is a common benchmark for rigorous qualitative research.[11,12] Saturation refers to the point in which no new information, ideas, opinions, or patterns emerge from the interviews, thus signaling that no new data are being generated.[11,13] Therefore, given the entire research team's expertise in the subject matter and the study's qualitative design,[13] we decided that we reached the saturation point at 18 interviews and recruitment for the study ended.

Participants were recruited from June to October 2021, with a study flyer that was disseminated via professional networks, including clinics, a state-level membership organization of ophthalmologists, and practicing ophthalmologists associated with the research team. Participants consented verbally prior to data collection and were provided the opportunity to end their participation in the research at any time during the interview. Interviews were conducted by the lead author and recorded using Zoom, lasting approximately 30 minutes. Interviews were transcribed verbatim by a professional transcription company for analysis. As participation in this study required taking part in an interview, participation was not anonymous. However, all interview transcripts were thoroughly de-identified by the interviewer prior to analysis. Only the lead author had information that could identify the participants.

A semi-structured interview guide, informed by clinical expertise of the research team and existing literature, led the question-asking process. The interview guide consisted of close-ended demographic questions and open-ended interview questions. Interviews were conducted until saturation was reached, which is when very little new information was presented in the interviews.[13,14] All study activities received human ethics board approval prior to participant recruitment.

De-identified transcripts were analyzed using qualitative thematic analysis techniques with QSR's Nvivo12 qualitative analysis software.[15,16] Two members of the research team engaged in the analysis process by first reviewing the transcripts in depth and then iteratively developing a codebook to guide analysis. Each interview was coded by both researchers, and segments of text were highlighted using the codebook as a guide. This produced overall thematic findings, which are described in the next section.

Results

Participants ($N = 18$) predominately identified as male ($n = 11$, 61%) and ranged in age from 25 to 44 years (mean = 32.3 years). Eight participants identified as white (44%) and 39% identified as Asian/Pacific Islander. Attending clinicians represented approximately 44% ($n = 8$) of the sample, as did ophthalmology residents (44%, $n = 8$). One ophthalmology fellow (6%) and one medical student (6%) participated as well. The vast majority of participants practiced ophthalmology within an academic setting ($n = 14$, 78%), while the remaining were at private practices ($n = 4$, 22%). Participants reported having < 1 year to 11 years of training in ophthalmology (mean = 4 years). Table 1 presents the participants' demographic information.

Three overarching themes from the interviews highlighted a baseline understanding of how AI currently is or could be integrated into clinical practice. These themes are:

1. AI has high utility in ophthalmology.
2. AI is a tool, but a balance between AI and the clinician is important.
3. Several challenges to integrating and accessing AI need to be addressed.

Patterns across these themes were examined in relation to participant demographics; however, no notable differences emerged based on age, years of training, practice setting, or other demographic characteristics.

Theme 1: AI has high utility in ophthalmology

All participants believed that AI informed practice was highly important in ophthalmology, particularly in screening, early diagnosis, and streamlining diagnostic procedures. A few participants characterized AI as being the future of clinical practice, suggesting that AI "can [diagnose] faster and more accurately" (ID04) and that "AI will be one of the future tools that can bridge the shortage of specialists and lack of equipment [in underserved areas]" (ID07). Participants also discussed the

Table 1. Participant demographics

Participants (N = 18)	Percent (Frequency)
Race/Ethnicity	
White	44.4% (8)
Asian/Pacific Islander	38.9% (7)
Two or more races	5.6% (1)
Other	11.1% (2)
Gender	
Male	61.1% (11)
Female	38.8% (7)
Age	
Range	25 to 44 years
Mean	32.3 years
Training	
Attending	44.4% (8)
Resident	44.4% (8)
Fellow	5.6% (1)
Student	5.6% (1)
Years of training	
Range	< 1 to 11 years
Mean	4.0 years

aggregation of clinical data using AI to detect patterns and predict risk factors that cannot always be detected through a clinical exam. Related to this, one participant commented, “the computer system is able to give us things that we’re unable to see” (ID08).

When asked about the specific procedures or eye conditions in which AI is particularly useful, several participants discussed application to optical coherence tomography (OCT) testing and intraocular lens (IOL) calculations. Speaking of IOL calculations, one participant commented, “It can be used for stratifying clinical risk factors, like in diabetic retinopathy. One, AI helps us catch more people that way, or at least screen them and get them seen by ophthalmologists that can like further to stratify that. Two, AI helps with the number of specialists or retina specialists or whoever’s reviewing the photos to be able to spend more time with patients.” (ID03).

Participants believe AI informed clinical practice is beneficial in identifying disease progression of certain eye conditions. For example, one person said, “With cataracts, it might be more of a one-time thing used in diagnosis. But for some other diseases, we look at many images, and it would be helpful to see the progression of the disease through AI by looking at those images.” (ID01). Glaucoma and diabetic retinopathy were listed as the top 2 eye conditions in which AI could have impact. One participant said, “Glaucoma is one area that may lend itself to future AI practice, particularly with regards to a patient who has possible/early glaucoma and trying to risk stratify them.” (ID12). Several other eye conditions were noted as well, such as age-related macular degeneration, cataracts, and keratoconus. Broadly, participants identified AI as being beneficial to many corneal and retinal conditions.

In addition, when asked about the comparison of AI to traditional statistical methods, participants reported that AI is more efficient, accurate, reliable, and robust. One participant summed this up by stating, “AI involves machine learning and very complex algorithms can consider many variables that are unique to a person, and I think that helps synthesize a more accurate and more reliable outcome.” (ID05). Several participants noted that large datasets are needed to make AI work, for instance, “The more data we can feed into, the more patient population data we can put into systems, the more accurate it’s going to be, eventually, it will be more reliable than then sort of just comparing normative values.” (ID02).

While all participants identified benefits of AI to patient health outcomes and clinical practice, very few participants had used AI in their own practice. One participant stated, “We use image analysis all the time, but it’s mostly you get a printout of results, and you have to manually go through and compare the patient’s data to normative values. There are some, it’s not really AI, but it’ll tell you if it’s in a normative range or above or below normative range. In terms of AI, oddly mostly in lens formulas, there are a couple out there that are sort of evolving based on

AI." (ID02). Similarly, while all participants were able to provide a broad definition of AI and its application to ophthalmology, they struggled with offering a specific definition and providing examples within their clinical setting. Almost all participants had never used ML in their own practice and relied upon conferences and academic journals to learn more about advances of AI in the field. Nonetheless, all participants believed there is opportunity to integrate AI into their own future practice. For instance, one participant could foresee using it more with "anterior segment cataract refractive surgery" in his own practice (ID03), and another commented that she would like to see it "implemented in all kinds of image analysis" (ID10).

Theme 2: AI is a tool, but a balance with the clinician is Important

Participants largely described AI as another tool they can use in clinical practice. In regard to AI-generated output, one participant said, "The clinician can use that interpretation, and use it in their interpretation and decision making." (ID16). One participant compared AI to the scientific process he uses in research and practice, stating that AI helps clinicians in "synthesizing everything that you know and comparing it to what people are doing" (ID05). Another participant commented, "Clinicians who are experienced know what mild, moderate, and severe diseases are and how they think that should be treated... AI can provide some reconsideration for what you might think is akin to having an expert colleague, in some ways, providing their opinion on how you might be treating that patient." (ID17).

The vast majority of participants described how AI can be used as a tool to help mitigate clinician bias. They recognized that human bias is inherent, and clinicians must actively work to avoid it in their clinical decision-making. One participant said, "Sometimes the human's judgment could be clouded by extraneous factors. It's going to be less biased than a human." (ID14). Another commented, "I think it can help us remove human bias. I think one of the goals is that if it's done correctly and if the data are comprehensive enough, then it could help us remove bias." (ID15). Related, another participant spoke about potential bias that can occur when a clinician experiences success with a particular approach and may get comfortable with that approach. This participant commented, "It's easy that we fall into observer bias traps where it's something that worked once or twice, you'd be tempted to keep doing the same thing for every patient. So, ML or AI would help you constantly keep balancing yourself and not, you know, just relying on your own anecdotal experience." (ID05).

While AI was recognized as a tool, many participants noted that AI will not replace clinical assessment and decision-making. Instead, a balance between the AI and clinician is essential at all stages in the AI development process until the AI reaches practice. For instance, in speaking of working with big data to create algorithms that can inform risk assessment, one participant commented that "AI and machines can do 99%. You know, it'll be like they can do everything, and then, if they have [cases] where they're not sure about, then it gets reviewed by a person and then that gets fed back to the AI and it can kind of learn from that as well.” (ID03). One participant also noted, “The responsibility still relies upon us. How much to use it, how much to rely on it. It’s a good way to really elevate how we practice.” (ID04).

Theme 3: Several challenges to integrating and accessing AI need to be addressed

Despite acknowledging the high potential of AI informed practice, participants also expressed concern with the current state of AI within ophthalmology. Several participants expressed that additional research is needed to both generate and refine the big datasets needed to create the AI algorithms. Several spoke about their concerns regarding accuracy, reliability, and the ability to clinically correlate the AI. One participant said, “The reliability and repeatability of it. I don’t know exactly how it would be structured. But I think that’s always the issue with anything. Is this reliable? Is it repeatable? And repeatable by other people? And can they get the same result or inter-observer repeatability?” (ID18). Another commented, “We have to correlate it clinically too, to make sure that what the machine detected, you follow those patients for 5 to 10 years to see if it actually was meaningful.” (ID04). However, participants did express faith that the state of the science would evolve, as one participant highlighted, “It is a matter of time when things become more accurate, as we grow.” (ID07).

As described in the previous theme, participants also expressed that a balance between the AI and the clinician was important. For instance, one participant said, “There’s always becoming more reliant on technology and not being able to eventually do the screening itself. The next generation comes up, and they’re just relying on the AI to do it, then maybe they lose those clinical skills.” (ID03). Concern was also noted with potentially missing an important diagnosis, as highlighted by this participant, “We might miss that maybe the patient has something else entirely. Maybe the AI doesn’t say, or the photo doesn’t show that, but it’s not trained to recognize some other rare thing that maybe this patient has.” (ID11). Several participants also recognized that although AI can potentially reduce human bias in clinical decision-making, bias can still exist with AI algorithms. While this bias may be different than inherent clinician bias, there are still people behind the algorithms which have that inherent human bias. Therefore, critical thinking and decision-making were vital.

Lastly, some participants noted cost barriers associated with new technologies, as well as the skills needed to use the technology. One participant said, “Any new technology, I think, has a cost associated with it, as well as the expertise that is required to implement it.” (ID15). And another noted their biggest concern as, “Well, probably cost is always a barrier to consider. These machines probably are expensive, and not everybody’s technologically advanced with their own skill sets. There will probably be some generational differences in how it’s received.” (ID14).

Discussion

This study yielded 3 main themes in consideration of the current understanding and application of AI in ophthalmology practice: a high potential for clinical utility, a continued need for physician interaction, and significant concerns about rigor and bias in AI applications. Participants recognized the high potential of AI, describing it as *vital* and *the future of the profession*. While they receive information about AI from conferences and academic journals, few participants had actually used AI in their current practice, which aligns with existing research.[9] This disconnect may suggest a potential gap in formal training on AI within medical education and continuing professional development. Participants were largely self-taught or reliant on opportunistic exposure to AI topics, rather than receiving structured instruction that could equip them with the technical, ethical, and practical understanding necessary for critical engagement with AI tools. The inherent 'black box' nature of many AI systems—where underlying algorithms and decision-making processes are not easily interpretable—may further exacerbate this gap, making it more challenging for clinicians to trust, evaluate, or effectively incorporate these technologies into their practice. Nonetheless, participants saw value in using AI as a tool for early identification of risk factors and monitoring progression of eye disease. The majority of participants also noted its ability to mitigate the inherent human bias that can be introduced in a patient-provider relationship and can influence decision-making. While only a few participants integrate AI into practice, the study sample was notably young in terms of age and training. Further research is needed with a more diverse sample in regard to these demographic characteristics.

Study participants recognized that a balance between AI and the provider is essential, as the human element in assessing a patient and determining proper care cannot be replaced by a computer. This aligns with existing research in which ophthalmologists view AI as another tool they can use but that does not replace their role.[17] However, participants highlighted that further research and large datasets are needed to improve the accuracy and reliability of AI algorithms and to improve the automation of certain clinical functions. In that respect, AI needs to be trustworthy. As AI becomes more integrated into clinical care, it will also be important to consider how patients perceive these technologies. Patients may express a range of responses—from optimism about improved efficiency and accuracy, to concerns about privacy, depersonalization, or reduced human oversight. Understanding and addressing patient perspectives will be essential to fostering trust and ensuring the ethical implementation of AI in ophthalmology.

Trustworthiness is a topic that is central to the deployment and adoption of AI solutions. In the United States, the National Artificial Intelligence Initiative considers trustworthiness as one of the main pillars towards advancing AI applications.18 Likewise, the European Commission appointed a group of experts to provide advice on its AI strategy,[19] which included a set of guidelines to assess for trustworthiness of AI systems. Participants of the current study were highly attuned to the need for trustworthy AI, as they noted such systems can both help mitigate and facilitate bias. AI systems within ophthalmology, and elsewhere, are either explicitly based on specific human expert knowledge or implicitly through ML from training databases. Both explicit and implicit bias is a major concern. For example, glaucoma incidence in the United States is higher in people of African descent than of European descent, with also more severe progression and vision loss.[20] And yet, the studies used to train algorithms may not reflect this disparity, potentially introducing bias.

This underrepresentation in training data can result in systemic biases that affect diagnostic accuracy, treatment recommendations, and ultimately health outcomes. Recently, significant heterogeneity was identified in blood vessel density biomarkers in eyes between glaucoma patients of African and European descent, and differences in pigmentation and reference groups may bias comparisons.[21] As a result, AI tools may generalize poorly or inequitably across diverse patient populations, exacerbating existing health disparities rather than alleviating them. Therefore, it is crucial that we explicitly keep rigor of data central in the development of AI systems, and carefully note the limitations encountered due to factors such as dataset size, coverage, and diversity. Developers must critically evaluate the composition of training datasets, ensure inclusion of historically marginalized groups, and conduct fairness audits that assess model performance across subpopulations. Without these safeguards, AI tools risk reinforcing structural inequities under the guise of technological objectivity. In ophthalmology—where early detection and precision matter greatly—ensuring that AI systems are equitable and inclusive is not only a technical necessity but an ethical imperative.

In summary, participants believe there is great utility of AI within ophthalmology practice, however a balance between the clinician and the AI is important, and concerns about rigor and bias in AI exist. With these findings, the authors recommend integrating structured AI education across medical education training and continuing education opportunities. Incorporating AI tools and literacy into ophthalmology residency/fellowship programs and continuing education workshops, including modules on ML principles, ethical considerations, and real-world case studies, would potentially help bridge the gap between training and practice. With this, trustworthiness should be considered as a core metric in AI evaluation. This may include aligning with national and international guidelines (*e.g.*, US National AI Initiative, EU Trustworthy AI framework) to assess trustworthiness, including transparency, accountability, robustness, and ethical use.

Limitations

While a great amount of rigor was employed in this qualitative study, findings are limited in generalizability due to the nature of its exploratory approach. A convenience sample was used to recruit participants, which limits the study generalizability beyond the demographics of the study sample. This includes limits in generalizability due to the age of participants. This sample represented a younger generation of ophthalmologists with a mean of 4 years as practitioners. As younger generations may have more experience with AI in general, they may be more prone to adopting AI in practice. In addition, as is true with all qualitative research, the interpretation of findings by the lead investigator can introduce bias. This limitation was addressed by using 2 researchers to engage in the development of the codebook and coding.

Conclusions

This study explored understanding and application of AI within clinical ophthalmology. Although findings yielded generally favorable views suggesting high potential for benefit with integration of AI systems, several barriers to adoption were noted by participants. While participants believe AI is the future of ophthalmology, a balance between the clinician and the computer is vital and concerns related to trustworthiness of the data were a consistent finding. This research lays important groundwork for understanding the clinical adoption of AI and challenges to its integration in practice.

Declarations

Ethics approval and consent to participate

This research was approved by the University of Missouri Institutional Review Board (Project # 2056102). All participants provided verbal informed consent prior to engaging in this research.

Competing interests

Giovanna Guidoboni would like to disclose that she has received remuneration from Qlaris and Foresite Healthcare to serve as a consultant. These relationships are pursuant to University of Maine's policy on outside activities. She also serves as Chief and Managing Editor of AIVO. Alon Harris would like to disclose that he received remuneration from AdOM, Qlaris, and Cipla for serving as a consultant, and he serves on the board of AdOM, Qlaris and SlitLed. Alon Harris holds an ownership interest in AdOM, Oxymap, Qlaris, SlitLed, and AEYE Health. He serves as Chief Editor of AIVO. Alice Verticchio Vercellin is an external collaborator of the IRCCS Fondazione Bietti, Rome. If you have questions regarding paid relationships that your physician/researcher may have with industry, you are encouraged to talk with your physician/researcher, or check for industry relationships posted on individual faculty pages on our website athttp://icahn.mssm.edu/.

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Author contributions
ELR served as principal investigator for this study and led the study design, data collection, analysis, and dissemination activities. GG is the PI of the grant which funded the current study and provided expertise in the study design, interpretation of findings, and dissemination. AV is a member of the research team and provided clinical and research expertise in the study design, interpretation of findings, and dissemination. RZ is a member of the research team and provided clinical in the study design and dissemination, and assisted with recruitment efforts. JK is a Co-I of the grant that funded the current study and provided expertise in AI and ML. BSA is a member of the research team and provided research expertise in the study design, interpretation of findings, dissemination. AH is a Co-PI of the grant that funded the current study and provided expertise in clinical ophthalmology and research, as well as interpretation of findings and dissemination. All contributors listed participated in development of the manuscript and provided final approval prior to submission.

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References

1. Malik P, Pathania M, Rathaur VK. Overview of artificial intelligence in medicine. J Fam Med Prim Care. 2019;8(7):2328–31. https://doi.org/10.4103/jfmpc.jfmpc_440_19
2. Wang L, Zhang Y, Wang D, et al. Artificial intelligence for COVID-19: a systematic review. Front Med (Lausanne). 2021;8:745719. https://doi.org/10.3389/fmed.2021.704256
3. Hogarty DT, Mackey DA, Hewitt AW. Current state and future prospects of artificial intelligence in ophthalmology: a review. Clin Exp Ophthalmol. 2019;47(1):128–39. https://doi.org/10.1111/ceo.13381

4. Nunez R, Harris A, Ibrahim O, et al. Artificial intelligence to aid glaucoma diagnosis and monitoring: state of the art and new directions. Photonics. 2022;9(11):810. https://doi.org/10.3390/photonics9110810
5. Ahn JM, Kim S, Ahn KS, Cho SH, Lee KB, Kim US. A deep learning model for the detection of both advanced and early glaucoma using fundus photography. PLoS One. 2018;13(11):e0207982. https://doi.org/10.1371/journal.pone.0207982
6. Wang M, Tichelaar J, Pasquale LR, et al. Characterization of central visual field loss in end-stage glaucoma by unsupervised artificial intelligence. JAMA Ophthalmol. 2020;138(2):190–8. https://doi.org/10.1001/jamaophthalmol.2019.5413
7. Medeiros FA, Jammal AA, Thompson AC. From machine to machine: an OCT-trained deep learning algorithm for objective quantification of glaucomatous damage in fundus photographs. Ophthalmology. 2019;126(4):513–21. https://doi.org/10.1016/j.ophtha.2018.12.033
8. Harris A, Guidoboni G, Siesky B, et al. Ocular blood flow as a clinical observation: value, limitations and data analysis. Prog Retin Eye Res. 2020;78:100841. https://doi.org/10.1016/j.preteyeres.2020.100841
9. Scheetz J, Rothschild P, McGuinness M, et al. A survey of clinicians on the use of artificial intelligence in ophthalmology, dermatology, radiology and radiation oncology. Sci Rep. 2021;11:5193. https://doi.org/10.1038/s41598-021-84698-5
10. Hennink M, Kaiser BN. Sample sizes for saturation in qualitative research: a systematic review of empirical tests. Soc Sci Med. 2022;292:114523. https://doi.org/10.1016/j.socscimed.2021.114523
11. Creswell JW. Educational research: planning, conducting, and evaluating quantitative and qualitative research. 5th ed. Boston: Pearson Higher Ed; 2015.
12. Marshall B, Cardon P, Poddar A, Fontenot R. Does sample size matter in qualitative research? A review of qualitative interviews in IS research. J Comput Inf Syst. 2013;54(1):11–22. https://doi.org/10.1080/08874417.2013.11645667
13. Guest G, Namey E, Chen M. A simple method to assess and report thematic saturation in qualitative research. PLoS One. 2020;15(5):e0232076. https://doi.org/10.1371/journal.pone.0232076
14. Guest G, Bunce A, Johnson L. How many interviews are enough? An experiment with data saturation and variability. Field Methods. 2006;18(1):59–82. https://doi.org/10.1177/1525822X05279903
15. Saldaña J. The coding manual for qualitative researchers. 4th ed. London: SAGE; 2021.
16. Guest G, MacQueen KM, Namey EE. Applied thematic analysis. Thousand Oaks: SAGE; 2012.
17. Gunasekeran DV, Zheng F, Lim GY, Chong CC, Zhang S, Ng WY, et al. Acceptance and perception of artificial intelligence usability in eye care (APPRAISE) for ophthalmologists: a multinational perspective. Front Med (Lausanne). 2022;9:875242. https://doi.org/10.3389/fmed.2022.875242
18. National Artificial Intelligence Office. Advancing trustworthy AI [Internet]. Washington (DC): US Government; 2023 [cited 2023 Feb 26]. Available from: https://www.ai.gov/strategic-pillars/advancing-trustworthy-ai/
19. European Commission. High-level expert group on artificial intelligence [online]. 2023. [Accessed 26 Feb 2023] Available from: https://digital-strategy.ec.europa.eu/en/policies/expert-group-ai
20. Siesky B, Harris A, Vercellin ACV, Guidoboni G, Tsai JC. Ocular blood flow as it relates to race and disease on glaucoma. Adv Ophthalmol Optom. 2021 Aug;6:245-262. https://doi.org/10.1016/j.yaoo.2021.04.016

21. Siesky B, Harris A, Verticchio Vercellin A, et al. Heterogeneity of Ocular Hemodynamic Biomarkers among Open Angle Glaucoma Patients of African and European Descent. J Clin Med. 2023 Feb 6;12(4):1287. https://doi.org/10.3390/jcm12041287