The Present and Future of Artificial Intelligence in Ophthalmology

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Artificial intelligence (AI), the use of machines to perform tasks that typically require human intelligence, has revolutionized industries and is set to alter the future of healthcare. Unlike traditional decision-making which uses a predetermined set of instructions, AI utilizes data input by users to create a decision-making algorithm. These self-learning, data-driven algorithms can analyze large volumes of data and draw conclusions with astounding accuracy. Although AI may pose legitimate concerns such as job automation and data security[1], ultimately these tools may assist and improve human decision-making performance, such as in healthcare providers. In particular, several ophthalmology studies have already demonstrated AI's ability to help physicians screen, diagnose, and treat ocular diseases[2].

Dr. Ravi Goel is a comprehensive ophthalmologist and cataract surgeon at Wills Eye Hospital, with a specific interest in finding ways that AI can help ophthalmologists improve their clinical care and treat more patients. Dr. Goel also publishes a daily blog, Protecting Sight, where he discusses a variety of topics ranging from advances in cataract surgery to medical education. One common thread throughout his blog is the burgeoning impact of AI on the field of ophthalmology, such as the utility of deep learning algorithms for diagnosing various diseases and the impact that improved intra-ocular lens (IOL) power calculations will have on patient care. We sat down with Dr. Goel to learn more about the effects that AI will have on the field of ophthalmology and hear his thoughts about what the future holds for this exciting corner of medicine.

How do you think AI will affect your practice? What are some of the current advantages and limitations?

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Dr. Goel is a firm believer in the potential of AI to improve the field of ophthalmology. According to the World Health Organization (WHO), 80% of visual impairment is preventable and curable. Dr. Goel believes that "the clear advantage of AI in ophthalmology is that it can lead us to treatment and diagnosis earlier." Guided by AI, earlier diagnosis and treatment of retinal and anterior segment eye conditions would vastly improve patient outcomes[3].

One of the main advantages for the use of AI in ophthalmology is that imaging-based medical fields have amassed enormous datasets from which AI can be trained. The more data the artificial neural network receives, the more accurate its

results will be. For example, using data from nearly 285,000 patients, AI was able to predict a patient's sex from their fundus photography with an astonishing 97% accuracy[4].

Although this technology seems promising, it is not without its limitations. If you wanted to know the algorithm used to predict sex based on imaging, that insight is currently unavailable due to what is known as the "black-box" problem (defined inputs and outputs with an unknown algorithm). Additionally, due to the AI's specialized focus on answering one very specific question at a time, a primary challenge that Dr. Goel cited was the need to monitor advances in AI in other medical and surgical subspecialties[2]. By collaborating with and taking inspiration from other specialties or industries entirely, both physicians and their partners could advance their respective fields.

How do you feel the field of ophthalmology will change to become more conducive to the use of artificial intelligence in the next 5-10 years?

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"The challenge for ophthalmology will be that we have to come together and improve the way we record data," Dr. Goel says. AI decision-making algorithms are only as reliable as the data from which they were trained. Fortunately, the American Academy of Ophthalmology (AAO) created the IRIS (Intelligent Research In

Sight) Registry, the world's largest specialty clinical database. This collaboration will allow participating entities to have larger study sample sizes for greater statistical power and can be used to evaluate clinical performance metrics, improve patient care, and develop stronger AI algorithms[5]. However, Dr. Goel mentioned that some large electronic medical record companies like Epic have yet to contribute data to the IRIS Registry. With time, the hope is that such large entities will contribute to these shared clinical databases with the goal of improving patient care.

In addition, some of the most promising research in AI and ophthalmology, in Dr. Goel's opinion, is related to diabetic retinopathy (DR) and cataract surgery. For DR, earlier detection and treatment can dramatically slow disease progression[6]. Notably, in August of 2020, the FDA cleared the EyeArt autonomous AI system

Dr. Ravi Goel
Credit: AMA

for DR screening[7]. In cataract surgery, AI may help improve the performance of IOL calculation formulas[8]. With its potential integration into automated refraction devices, AI may help provide an improved framework for IOL formula optimization that is more accurate and customized to a specific cataract surgeon.

Although the possibilities of AI may seem endless, its applications rely on human creativity to ask novel and meaningful questions. "The point of big data," Dr. Goel says, "is to answer questions we don't even know to ask yet." With increased collaboration, AI will be poised to improve healthcare and other fields.

> **Cataracts are the leading cause of visual impairment worldwide. Given your experience training abroad, how do you feel AI can help ophthalmologists exert a greater impact on patients around the world, especially those in lower income countries/communities?**
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> *"In some other countries, [ophthalmologists] have to choose which eye to treat because they don't have the resources to treat both eyes for everyone."*

There are over 285 million visually impaired people around the world, with 90% of patients living in developing countries[9]. In the coming years, this number will likely continue to grow due to longer patient lifespans and chronic diseases that impair vision.

With these statistics in mind, Dr. Goel believes that one of the biggest obstacles facing ophthalmologists worldwide is a massive mismatch between the supply of ophthalmologists and the demand for treatment. "In some other countries," he explains, "[ophthalmologists] have to choose which eye to treat because they don't have the resources to treat both eyes for everyone." This disturbing reality is corroborated by Owen O'Donnell, who explains that one of the biggest issues in low- and middle-income countries is limited access to healthcare[10]. Dr. Goel believes that future innovations in AI will serve to expand the reach an individual ophthalmologist can make, allowing them to begin attacking this massive disparity. He explains, "if AI can free up my time to do surgery instead of dry eye exams, I can be a bigger help to more patients." Although this will not completely address the supply-demand disparity, he believes that optimization of his time will allow him to make a substantial impact on a larger number of patients.

Various studies support this idea by showing that there is comparable diagnostic performance in using AI to screen, diagnose, predict and monitor various eye conditions on fundus photographs and optical coherence tomography, including DR, age-related macular degeneration, glaucoma, and retinopathy of prematurity (ROP)[11-14]. These studies posit that if ophthalmologists can use AI to more quickly diagnose a larger volume of patients with eye disorders, they will have more time to perform procedures and actually treat patients. With this in mind, if ophthalmologists are able to implement some of these AI technologies in developing countries around the world, they will begin addressing the supply-demand disparity issue in the places that experience the greatest disparities. In this way, we will be able to empower the field of ophthalmology to exert a greater impact on communities around the world.

The future of AI in the field of

ophthalmology is incredibly bright. Following our conversation with Dr. Goel, it is clear that AI may lead to improved diagnosis, superior treatment, and expanded access to care, with great potential for other improvements in the future. To continue to find ways for AI to enhance the field of ophthalmology, it is important for clinical staff to monitor other fields of medicine to look for inspiration. For example, using multiple sensors, Stanford's program AI-assisted care (PAC) can sense any behavioral changes in elderly people living alone[15] and ICU patients[16], respectively, which will allow for greater patient monitoring outside of the clinic. Ophthalmologists may be able to utilize a similar system to track medication adherence or post surgical recovery. Another potential lesson can be taken from Beth Israel Deaconess Medical Center, where a team of researchers created an AI diagnostic program that could identify cancer in pathology slides with 92% accuracy, nearly as accurate as a human pathologist at 96%. However, when they combined the AI program with the pathologist's analysis, the diagnostic accuracy improved to 99.5%[17]. Similar technology could potentially aid ocular oncologists with diagnosing complex rare or cancer cases. Such remarkable results suggest a promising future for physicians, assisted by the power of AI, to deliver better healthcare to even more patients.

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