New era after ChatGPT in ophthalmology: advances from data-based decision support to patient-centered generative artificial intelligence

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Artificial intelligence (AI) has permeated the medical field to enhance the experiences of clinicians and patients. Jiang *et al.* summarized the major publications and authors working on AI development in the ophthalmology field so far (1). To date, most studies have focused on designing models that help doctors make fast screenings or arrive at accurate medical decisions by learning from existing clinical data based on machine learning and convolutional neural networks (CNN) (2). Therefore, institutions that have extensive data on existing research medical have quickly developed AI models and have emerged as leaders in academia in this field. Most AI studies have targeted diabetic retinopathy, age-related macular degeneration, glaucoma, and cataracts based on epidemiological research data combined with large-scale fundus photographs and optical coherence tomography (OCT) (3,4). Based on the advances of deep learning technology, AI-based systems such as IDx-DR (Digital Diagnostics, Coralville, IA, USA) and EyeArt (Eyenuk, Los Angeles, CA, USA) have been approved for diabetic retinopathy detection by the US Food and Drug Administration (5). Several clinical trials have demonstrated that these AI systems can serve as low-cost point-of-care diabetic retinopathy detection tools (6). AI has been used in various fields, such as refractive correction surgery (7), ocular disease treatment (8), and oculomics (9). The AI models developed so far have focused on decision support systems for doctors.

Future perspectives on generative AI

In addition to existing data analyses based on the aforementioned technologies, AI technology that generates synthetic data has recently been introduced (*Figure 1*) (10). In the future, generative AI systems that promote patient convenience rather than doctors will be actively used in the new era of AI. Since the advent of ChatGPT, the public has been able to easily access and interact with AI on chat-like interfaces, which have rapidly accelerated its progress in all areas, including medicine (11). ChatGPT was developed based on GPT-3, a large language model trained to generate realistic texts. Based on its high level of natural language processing ability, it shows the ability to understand unstructured data, new content generation ability, and high versatility. Eventually, it is expected to quickly penetrate medical AI fields related to ophthalmology and expand its scope from simple questions and answers (Q&As) to

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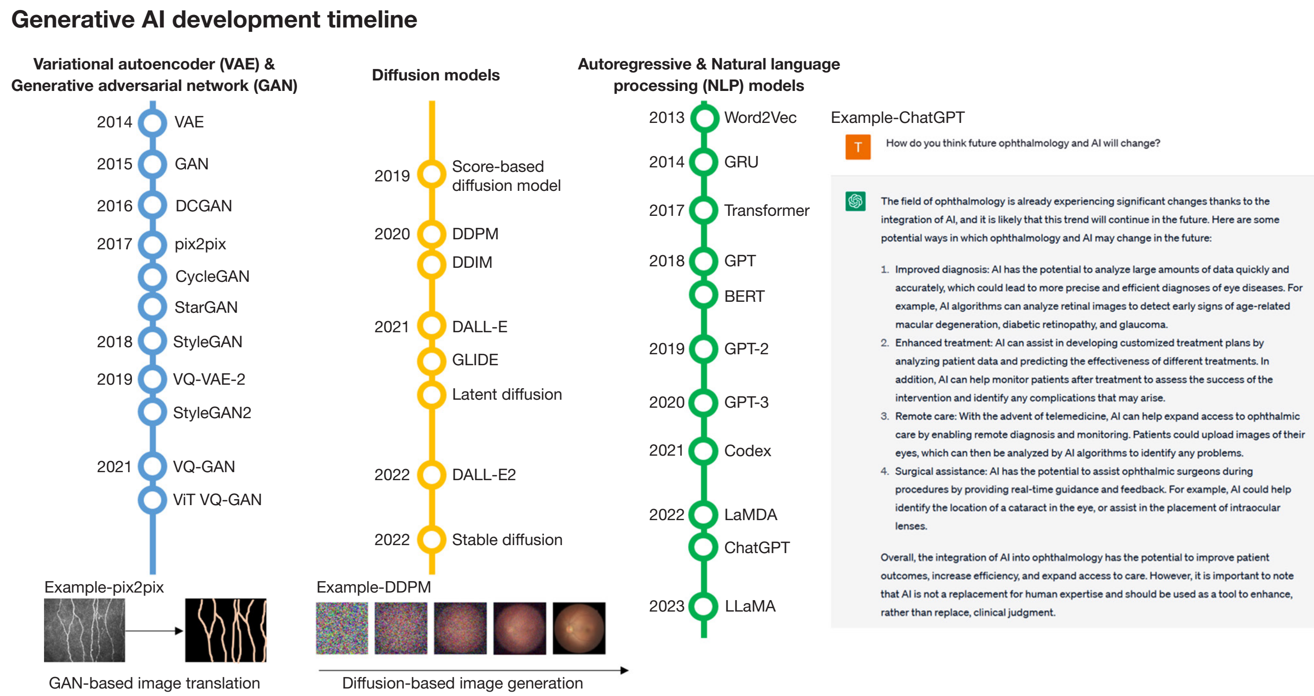

Figure 1 History of development of generative AI. AI, artificial intelligence; VAE, variational autoencoder; GAN, generative adversarial network; DCGAN, deep convolutional generative adversarial network; VQ, vector quantized; ViT, vision transformer; DDPM, denoising diffusion probabilistic model; DDIM, denoising diffusion implicit model; GLIDE, guided language-to-image diffusion for generation and editing; GRU, gated recurrent unit; GPT, generative pre-trained transformer; BERT, bidirectional encoder representations from transformers; LaMDA, Language Model for Dialogue Applications; LLaMA; Large Language Model Meta AI.

diagnostic care assistance.

Wang *et al.* conducted several studies based on a basic transformer architecture to analyze electronic medical records (12,13). Medical image generation using generative adversarial networks (GAN) has been conducted for ophthalmology imaging (14). Until now, these language processing and generative technologies have been used by ophthalmologists to solve detailed tasks; however, it is expected that patient-centered AI will be developed in the future, starting with ChatGPT. First, there is an era of searching for and inquiring about patients' ophthalmic knowledge based on chatbots (15). The future advanced chatbot model does not simply refer to medical text data but also to the analysis of medical records, including ophthalmology images, and notification of analysis results. Secondly, patients can predict the course of future diseases; therefore, they can use various ophthalmological imaging domains based on generative AI (16). This can convey the characteristics and prognosis of the disease to patients more effectively than simple language delivery. For example, patients can understand how the shape of their macula changes after retinal surgery and decide on the surgery (17). The development of diffusion models beyond GAN will make this possible in the future (18,19). Third, smoother communication in telemedicine is possible through new interactive tools based on generated AI, such as virtual humans (digital humans) (20). Virtual doctors can be shown to patients naturally through generative AI, without being constrained by language, using text-to-speech technology. In areas where doctors are scarce, patients can easily understand various types of medical information through virtual humans.

Limitations of generative AI

However, generative AI currently has certain disadvantages. Currently, conventional CNN models can operate on personal computers with graphics cards; however, most large generative models, including ChatGPT, require a large amount of computation and can operate only in large computational environments. This limits the dissemination of new technologies. In addition, shortcomings that must be addressed include difficulties in providing the latest information, frequent errors, and insufficient performance. Owing to the difficulty of learning large models, the latest medical knowledge, especially recent research results, is likely to have difficulty providing information. The provision of inaccurate information in the medical field can cause fatal problems. Although diffusion models continue to appear in the field of image generation following GAN, they still exhibit insufficient performance for generating realistic images. Though so far, the importance of training data has been reported, but the algorithms have not overcome the limitations of small data. Therefore, it is necessary to continue development through continuous data collection and advanced algorithm development.

Conclusions

The article by Jiang *et al.* summarized the flow of international AI research in ophthalmology over the last decade (1). Just in time, AI in academia and industries are also facing a new phase. AI development in the field of ophthalmology is also expected to enter a new era that will not simply help doctors improve screening accuracy. Patients are increasingly able to use AI and enhance their lives. In the future, research groups that use large generative models effectively and are competent at fine-tuning to adapt large foundation models to their specific tasks will emerge as new leaders in the field of ophthalmology and AI.

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