SHORT COMMUNICATION

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Is Artificial Intelligence an accurate tool for improving access to ophthalmological services in rural areas? A narrative review

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Abstract

Introduction. The integration of artificial intelligence (AI) in ophthalmology, specifically through the use of Optical Coherence Tomography (OCT) images, has marked a significant advancement in the detection and management of ocular diseases. The article compares the detection of eye conditions by health professionals using Optical Coherence Tomography (OCT) with AI abilities.

Review Methods. Online databases were searched for articles discussing the effectiveness of AI in OCT analyses and assessment of the accuracy and agreement of AI algorithms with human experts. Key words included 'OCT', 'AI', 'comparison' and 'effectiveness''.

Results. AI algorithms have demonstrated the capability to automatically segment retinal layers, detect and quantify pathological changes, and predict disease progression. The application of AI helps address the challenge of artifacts in OCT images, enhancing the accuracy of tissue structure segmentation and improving diagnostic precision.

Conclusions. This article explores the comparative effectiveness of AI and human experts in diagnosing ocular conditions using OCT, highlighting AI's potential to complement human expertise and improve patient outcomes. Despite the promising results, variability in AI performance across different studies underscores the need for more robust and standardized AI models, along with high-quality, diverse datasets to ensure consistent and generalizable results.

Key words
ophthalmology, artificial intelligence, eye health, AI in ophtalmology

INTRODUCTION AND OBJECTIVE

Eyesight is a crucial sense that significantly influences social functions and the ability to perform daily activities, including work [1]. Despite its importance, eye health is often neglected. Eye health encompasses vision defects and diseases caused by infections, genetic factors, or aging, often with a chronic course. Common eye diseases include glaucoma, cataracts, age-related macular degeneration (AMD), and diabetic retinopathy (DR) [2].

These conditions can progress asymptomatically over a long period of time [3]. Common visual impairments, such as myopia, astigmatism and hyperopia, are particularly critical to correct as a preventive tool for further problems. The number of people at any age affected by the conditions leading to vision loss is increasing substantially as the population increases and ages [3]. Preventable vision loss such as cataracts and refractive error remain the number one cause of most cases of blindness and moderate to severe vision impairment in adults [4]. The majority of eye conditions are painless and not characterized by obvious and rapid symptoms, therefore frequent screening is crucial. Eye health and vision exert crucial and profound implications for qualitative life, good health, human progress, and sustainable income [5]. Yet nowadays, communities are suffering from the consequences of poor awareness of eye care and eye prophylaxis leading to otherwise avoidable vision impairment and blindness [6]. The same problems also concerns the Polish population where, especially in rural areas, people face serious difficulties with assessing ophthalmological examinations, a situation dictated by a lack of specialists, poor awareness of age-related eye problems, and costs of private services.

By 2050, the World Health Organization (WHO) estimates that the aging population and urbanization might lead to 895 million people being affected by distant vision impairment, of whom 61 million will be completely blind [7]. In Poland, approximately three-quarters of the adult population have visual impairments [8], but society, especially in the rural areas has a problem with access to specialists [9]. An increased number of eye health services would allow the examination of increasing numbers of patients and address avoidable vision loss [10]. The involvement of artificial intelligence (AI) in screening for eye problems may be another solution for the wider availability of ophthalmological services. AI has advanced significantly in recent years, particularly in medicine, including ophthalmology, assisting in the diagnosis of specific eye conditions [11]. The article compares the detection of eye conditions by health professionals using

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Optical Coherence Tomography (OCT) with AI- based methods to equalise the differences between rural and urban areas.

AI in medicine. AI can be divided into machine learning (ML) and deep learning (DL). ML systems learn autonomously from experience, improving their performance with increased exposure to data. They can process electronic health records for prognosis, diagnosis, and treatment, as well as detect insurance claim fraud. DL – a subset of ML – uses multi-layered algorithmic constructs for data analysis, requiring multiple layers of codes and autonomously learning from training datasets. This is particularly useful in specialties with a heavy imaging focus, such as oncology, cardiology, orthopedics, neurology, pulmonology, gastroenterology, and ophthalmology [12]. AI algorithms developed based on OCT images can automatically segment retinal layers, detect and quantify pathological changes, and predict disease progression. AI helps in the detection of diseases such as AMD, glaucoma, macular edema, and DR. OCT images can depict artifacts that affect the accuracy of analysis by a physician, promoting the use of AI to correct these artifacts defects and improve tissue structure segmentation [12].

OCT as a diagnostic tool in ophthalmology. Optical Coherence Tomography (OCT) has revolutionized the field of ophthalmology by providing high-resolution, cross-sectional images of the retina and other ocular structures. This non-invasive imaging technique utilizes low-coherence interferometry to produce detailed 3D representations of the internal tissues of the eye. OCT is instrumental in diagnosing and monitoring a variety of eye conditions, including diabetic macular oedema, glaucoma, and age-related macular degeneration. By offering precise measurements of retinal thickness and integrity, OCT assists in tracking disease progression, assessing treatment efficacy, and guiding surgical interventions. Its ability to capture minute details enables early detection and timely management of ocular diseases, significantly improving patient outcomes [13].

REVIEW METHODS

Databases such as PubMed, Cochrane Library and Google Scholar were searched for articles discussing the effectiveness of AI in OCT analyses and assessment of the accuracy and agreement of AI algorithms with human expertise. Key words included 'OCT', 'AI', 'comparison', and 'effectiveness'. Articles published between 1 January 2015 – 1 July 2024 were taken into consideration for inclusion in the review. The selection of papers was based on the following inclusion criteria:

1) timeframe: only papers published between 2015–2024 were considered, excluding older studies to ensure current relevance and technological development;
2) methodological rigor: studies must have used a mixed methods approach;
   a) sample size was stated and clearly specified;
   b) clear description of data collection and analysis procedures;
   c) topic specificity;
   d) focus exclusively on AI work productivity in ophthalmology;
   e) quality indicators;
   f) published in peer-reviewed journals with open access;
   g) precise reporting of limitations and potential biases;
   h) complete presentation of findings with supporting data.

From an initial pool of 45 papers, 41 were excluded for the following reasons:

1) use of only quantitative methods (15 papers);
2) unclear sample sizes (15 papers);
3) published before 2019 (6 papers);
4) lacked methodological clarity (3 papers);
5) incomplete data presentation (2 papers).

Results of remaining articles are summarized in Table 1.

DISCUSSION

The results of the study highlight the significant potential and current limitations of AI in analyzing OCT images for various ocular conditions. The accuracy and agreement of AI algorithms with human expertise are notable, particularly in the study by Midena et al. (2023) [14], where the AI achieved accuracy rates between 94.7% – 95.7% in diagnosing diabetic macular oedema, with kappa values indicating a high level of agreement with human expertise (0.831 – 0.936). These findings underscore the reliability of AI in interpreting OCT parameters for this specific condition. Similarly, Bai et al. (2022) [15] demonstrated that AI could effectively diagnose a range of 15 different retinal disorders, with sensitivity rates from 87.65% – 100%, and specificity between 80.12% – 99.41%. However, the variability in kappa values (0.579 – 0.731) suggests that while AI performs well, there is still room for improvement in achieving consistency across different conditions.

Table 1. Assessment of accuracy and agreement of AI algorithms with human expertise

Article	Disease	Number of Eyes Diagnosed	Results	Additional Notes
Midena.E, et al, 2023 [VI] 14	Diabetic macular edema – major oct parameters	303	AI algorithm accuracy for OCT parameters: 94.7% to 95.7% Agreement with human experts: Kappa values: 0.831 – 0.936	-
Bai J, et al, 2022 [VII] 15	15 different retinal disorders	878	sensitivity: 87.65–100%, and specificity: 80.12–99.41%; Kappa values: 0.579–0.731	-
Mohammadpour M, et al, 2022 [VIII] 16	Keratoconus	424	subclinical keratoconus (SKCN) – sensitivity: 26.92 – 84.62%; specifity: 86.08–97.50%; kappa score: 0.29–0.7 KCN – sensitivity: 67.75 – 95.59%; specifity: 84.03–96.45%; kappa score: 0.68 – 0.79	4 different AI classifiers
Lin H, et al, 2019 [IX] 17	Cataract	350	AI: sensitivity: 89.7; specifity: 86.4% Senior Consultant: sensitivity: 98.4%; specifity: 99.6%	-

The study by Mohammadpour et al. (2022) [16] on keratoconus presents a more complex picture, with sensitivity and specificity varying significantly across different AI classifiers. The sensitivity for SKCN ranged from 26.92% – 84.62%, and specificity from 86.08% – 97.50%, indicating a broader range of performance. This variability was also reflected in the kappa scores (0.29 – 0.7), suggesting that the effectiveness of AI can be highly dependent on the specific algorithm and the dataset used. Lin et al. (2019) [16] compared AI performance in diagnosing cataracts to that of a senior consultant, revealing that while AI showed promising sensitivity (89.7%) and specificity (86.4%), it still lagged behind the performance of the senior consultant's (sensitivity: 98.4%, specificity: 99.6%). This comparison highlights that, although AI is advancing rapidly, it has not yet surpassed the expertise of seasoned human professionals in all areas.

These findings collectively illustrate that while AI holds great promise for enhancing diagnostic capabilities in ophthalmology through OCT imaging, there are still significant challenges to be addressed. The variability in AI performance across different studies and conditions indicates the need for more robust and standardized AI models. Additionally, the importance of comprehensive, diverse, and well-annotated datasets cannot be overstated, as they are crucial for training AI systems that are both accurate and can be generalized across different populations and disease states. Therefore, future research should focus on improving AI algorithms, ensuring high-quality data, and maintaining the complementary role of AI alongside human expertise in clinical practice.

CONCLUSIONS

Artificial intelligence has shown considerable promise in enhancing the accuracy and efficiency of OCT in diagnosing ocular fundus diseases. Comparing AI-based methods with traditional assessments by physicians indicates that AI can provide comparable diagnostic accuracy, particularly in such conditions as diabetic macular oedema and AMD. However, variability in AI performance across different studies and conditions highlights the need for more robust and standardized models. Continued advancements in AI technology, improved algorithms, and high-quality, diverse datasets are essential for achieving consistent results. The integration of AI with OCT will likely further improve early detection and management of eye diseases, ultimately enhancing patient outcomes while complementing human expertise. AI provides the possibility to align the disparities between urban and rural areas.

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