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Effectiveness of artificial intelligence for diabetic retinopathy screening in community in Binh Dinh Province, Vietnam

Thanh Nguyen Van[1]*, Hoang Lan Vo Thi[2]

Abstract:

PURPOSE: The objective of this study is to evaluate the sensitivity, specificity, and accuracy of artificial intelligence (AI) for diabetic retinopathy (DR) screening in community in Binh Dinh Province in Vietnam.

MATERIALS AND METHODS: This retrospective, descriptive, cross-sectional study assessed the DR screening efficacy of EyeArt system v2.0 by analyzing 2332 nonmydriatic digital fundus pictures of 583 diabetic patients from hospitals and health centers in Binh Dinh province. First, we selected thirty patients with 120 digital fundus pictures to perform the Kappa index by two eye doctors who would be responsible for the DR clinical feature evaluation and DR severity scale classification. Second, all digital fundus pictures were coded and then sent to the two above-mentioned eye doctors for the evaluation and classifications according to the International Committee of Ophthalmology's guidelines. Finally, DR severity scales with EyeArt were compared with those by eye doctors as a reference standard for EyeArt's effectiveness. All the data were analyzed using the SPSS software version 20.0. Values (with confidence interval 95%) of sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were calculated according to DR state, referable or not and vision-threatening DR state or not. $P < 0.05$ was considered statistically significant.

RESULTS: The sensitivity and specificity of EyeArt for DR screening were 94.1% and 87.2%. The sensitivity and specificity for referable DR and vision-threatening DR were 96.6%, 90.1%, and 100.0%, 92.2%. Accuracy for DR screening, referable DR, and vision-threatening DR were 88.9%, 91.4%, and 93.0%, respectively.

CONCLUSION: EyeArt AI was effective for DR screening in community.

Keywords:

Accuracy, artificial intelligence, diabetic retinopathy, sensitivity, specificity

Introduction

Diabetic retinopathy (DR) is one of the leading causes of blindness and vision impairment in adults aged over 50 years old in the world,[1] with a prevalence increasing from 14.9% in 1990 to 18.5% in 2020. According to the statistics of the International Committee of Ophthalmology (ICO), there was one in three people with diabetes has a DR and 10.2% of people with diabetes having a vision-threatening DR.[2]

The gold standard of DR diagnosis was the 7-field color stereoscopic fundus imaging or fluorescein angiography (FA) in accordance with the guidelines of Early Treatment Diabetic Retinopathy Study.[3] However, these techniques were not practical for DR screening in community, especially in the regions where specialized equipment and human resources for eye care were not available.[4,5] In recent years, digital fundus

[1]Department of Planning and Outreach, Binh Dinh Eye Hospital, Binh Dinh Province, [2]Department of Ophthalmology, University of Medicine and Pharmacy at Ho Chi Minh City, Ho Chi Minh, Vietnam

***Address for correspondence:**
Dr. Thanh Nguyen Van, 17 Nguyen Thien Thuat Street, Quy Nhon City, Binh Dinh Province, Vietnam.
E-mail: bsthanhbvmatbd@gmail.com

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cameras have been largely used as an alternative to 7-field color stereoscopic fundus cameras or FA in community-based DR screening. Furthermore, artificial intelligence (AI) has been established to make DR screening results faster, simpler, and more efficient.[6] The sensitivity and specificity of AI were 90.79% and 91.18%, respectively, according to He *et al*.[7]

Binh Dinh is a poor central coastal province with one city and 10 districts with a population of 1.6 million in Vietnam. The provincial eye-care network has been set up for a long time, but at the district level, there is no eye doctor capable of DR screening. In other words, the whole province does not have enough staff and equipment to diagnose and treat DR. Since 2019, nonmydriatic digital fundus imaging cameras have been used for DR screening in community in Binh Dinh. Since March 2021, an AI software (EyeArt) has been deployed throughout the province with many encouraging results. It was very necessary to evaluate the sensitivity, specificity, and accuracy of EyeArt AI software for DR screening in the community. The result will be a basis for developing a provincial plan to prevent DR in the coming years.

Materials and Methods

Study population and design

This retrospective, descriptive, cross-sectional study was performed on all patients with diabetes at hospitals and health centers in Binh Dinh province in Vietnam from March 2021 to October 2022. With the sensitivity[8] was 90%, the DR prevalence in community[2] in Binh Dinh was 30% and 10% of nonmydriatic digital fundus images were expected to be excluded for any reason, a sample size of 516 patients with 2064 digital fundus images were selected to carry out the study.

This study protocol adhered to the principles of the Declaration of Helsinki and was approved by the Institutional Review Board of the University of Medicine and Pharmacy at Ho Chi Minh City in Vietnam (IRB-VN01002/IORG0008603/FWA00023448), coded 22608-DHYD under the Reduced Procedure. Written informed consent was obtained from the patients in the study.

Inclusion and exclusion criteria

The inclusion criteria were all patients with diabetes, regardless of age, gender, and area of residence. All patients came to hospitals and health centers in the province to have their eyes examined and their fundi photographed. All patient's fundi were imaged with a nonmydriatic digital camera, Volk Optical (Pictor Plus™ Fundus Camera, image resolution of 2560 × 1920 pixels) or CR-2 AF (Canon CR2 Camera, image resolution of 32.5 megapixels). One patient had two digital fundus pictures for each eye, one centered on the macula and another centered on the optic disc. All retinal fundus pictures were automatically classified with EyeArt system v2.0 (Eyenuk, Inc., Los Angeles, CA, USA).

Exclusion criteria

(1) Patients who had experienced treatment with anti-VEGF or laser photo-coagulation, (2) those who with a second follow-up, (3) those who had one eye classified as non-DR and another ungradable due to any reasons, and (4) those who had not enough four digital fundus pictures or lacked the necessary information for the statistical analysis.

Description of parameters

The study indicators included (1) demographic variable (age, groups of age, and sex). Patient's age was categorized into <40 years old, 40–50 years old, 50–60 years old, 60–70 years old, and ≥70 years old, (2) DR clinical variable according to the ICO's guidelines,[2] (3) DR severity scale variable according to the ICO's guidelines (non-DR, mild nonproliferative diabetic retinopathy [NPDR], moderate NPDR, severe NPDR, and proliferative diabetic retinopathy [PDR]),[2] (4) referable DR variable[2] (if at least one eye has any of the following features: moderate NPDR, severe NPDR, PDR, noncentral-involved diabetic macular edema (DME), and central-involved DME), and (5) vision-threatening DR variable[2] (if at least one eye has any of the following features: severe NPDR, PDR, noncentral-involved DME, and central-involved DME).

Study protocol

The study protocol was as follows: First, we selected thirty patients with 120 digital fundus pictures to perform the Kappa index to obtain the consensus of two eye doctors who would be responsible for DR clinical feature evaluation and DR severity scale classification. A Kappa value of 0.7 and over would indicate a good reliability for the study deployment. Second, all digital fundus pictures were coded and then sent to the two above-mentioned eye doctors to be evaluated and classified according to the ICO's guidelines. Noted that these two eye doctors did not know any information about patients and DR severity scales classified with EyeArt. In the end, DR severity scales classified with EyeArt were compared with those by eye doctors as a reference standard for EyeArt's effectiveness.

Statistical analysis

All digital retinal fundus images that responded to the criteria were included in the analysis. If the four digital fundus photos were classified into different DR severity in one patient, the DR severity scale of the given patient was classified according to the image with the most severe damage. If the patient has at least one eye classified DR/referable DR/vision-threatening DR, the four digital fundus images of this patient are included for

the analysis. In contrast, the patient was excluded if she/he had two eyes classified as ungradable due to image quality or one eye classified as non-DR and another ungradable. If there was a disagreement between two eye doctors, these photos were sent to a DR expert at the Department of Ophthalmology, University of Medicine, and Pharmacy at Ho Chi Minh City for reading. Her DR severity scale was the last result.

All the data were analyzed using the SPSS software version 20.0 (IBM SPSS software, United States). The true positive, false positive, true negative, and false negative were determined on 2 × 2 table based on DR severity scales classified with EyeArt versus by eye doctor. The values (with confidence interval [CI] 95%) of sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were calculated according to DR state, referable DR state or not, and vision-threatening DR state or not. The continuous data were expressed as means with standard deviation. Ordinal and binary data were expressed as a percentage. Pearson or Fisher exact Chi-square test was used to determine the association between the qualitative variables. McNemar was used to determine the differences in a dichotomous dependent variable between two related groups. The DR severity is an ordinal variable, so the Chi-square test (Pearson or Fisher) is suitable for it. In meanwhile, the DR prevalence is a binary variable with two values of zero and one (0,1). In the study, each picture was evaluated as having a DR or not with EyeArt, then by Eye Doctor, so the McNemar test was suitable for this related binary variable (paired binary variable). The referral DR prevalence and the vision-threatening DR prevalence were similar. $P < 0.05$ was considered statistically significant.

Results

Kappa index of two eye doctors for consensus

A Kappa of ten clinical signs of DR per eye was evaluated for the consensus of two eye doctors. The Kappa of macular edema in the right eye and in the left eye was 0.839 and 0.800 with $P < 0.001$. Similarly, the Kappa of hard exudate in the right eye, in the left eye, and the Kappa of venous abnormality in the left eye were 0.918, 0.915, and 0.843 with $P < 0.001$, respectively. The Kappa of other clinical signs was 1.0 with $P < 0.001$. In addition, the Kappa of DR screening, referable DR, and vision-threatening DR was also 1.0 with a $P < 0.001$. This result showed a high consensus of two eye doctors.

Demographic characteristics

There were 684 coded and inputted patients, but only 583 patients (85.23%) with 2332 digital fundus pictures used for the statistical analysis [Figure 1]. The mean age was 61.8 ± 10.5 years old (median 62, max 90, min 16). There were 346 females, accounting for 59.3%. The female-to-male ratio was 1.46. The association between the groups of age, and sex was statistically significant with $P < 0.001$ (Pearson Chi-square) [Table 1 and Supplementary materials].

Diabetic retinopathy severity scales classified with artificial intelligence

According to the classification of EyeArt AI, the prevalence of moderate NPDR was the highest (14.4%), followed by

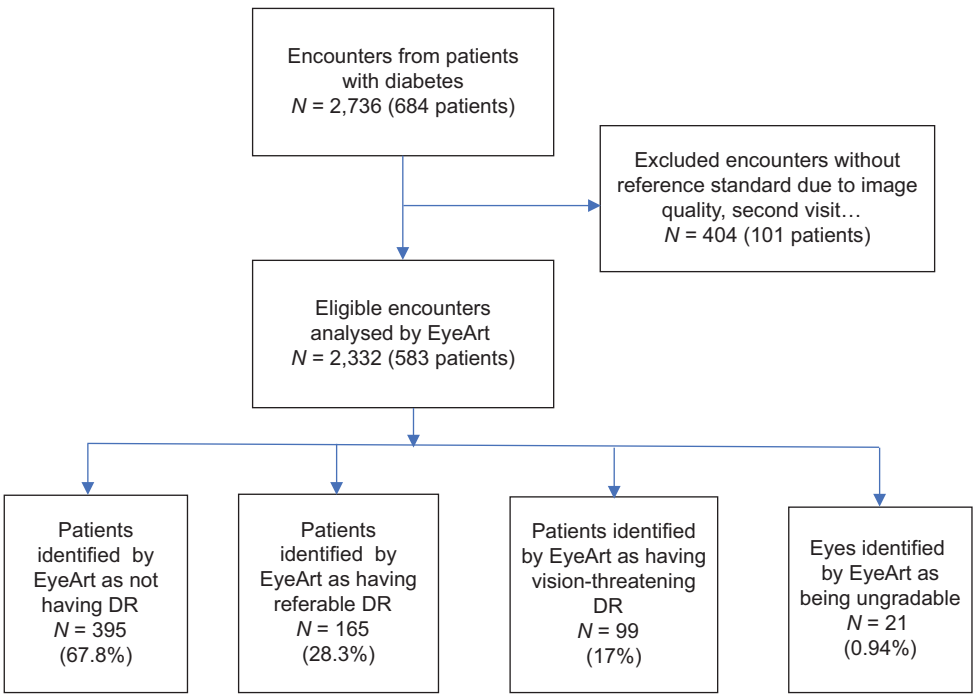

Figure 1: Flowchart showing the number of cases included and excluded

severe NPDR (8.7%). The prevalence of mild NPDR was similar to that of PDR (4.6% vs. 4.5%) [Table 2]. The association between DR severity and age, groups of age, and sex were not statistically significant with $P = 0.095$, 0.505, and 0.571, respectively (Pearson Chi-square).

Figure 2a shows the apparent difference in DR severity scales classified with EyeArt AI and by eye doctors. This difference was statistically significant with a $P < 0.001$ (Fisher's exact).

Diabetic retinopathy prevalence, referable diabetic retinopathy prevalence, and vision-threatening diabetic retinopathy prevalence

DR prevalence, referable DR prevalence, and vision-threatening DR prevalence classified with EyeArt were 32.2%, 28.3%, and 17.0%, respectively [Table 2].

The association between DR prevalence and age, groups of age, and sex was not statistically significant with a $P = 0.440$, 0.827, and 0.409, respectively (Pearson Chi-square). The association between referable DR prevalence and age, groups of age, and sex was not statistically significant with a $P = 0.475$, 0.773, and 0.796, respectively (Pearson Chi-square). The association between vision-threatening DR prevalence and age, groups of age, and sex was not statistically significant with a $P = 0.379$, 0.858, and 0.956, respectively (Pearson Chi-square).

Figure 2b shows the clear difference in DR prevalence, referable DR prevalence, and vision-threatening DR prevalence classified with EyeArt and by eye doctor. This difference was statistically significant with a $P < 0.001$ (McNemar).

Effectiveness of eyeart artificial intelligence software in diabetic retinopathy screening

The sensitivity, specificity, and accuracy of EyeArt AI software for DR screening were 94.1% (CI 95%:

Table 1: Demographic characteristics of the study sample

Groups of age/ sex (years old)	Female, *n* (%)	Male, *n* (%)	Total, *n* (%)
<40	8 (1.4)	12 (2.1)	20 (3.5)
40–50	20 (3.4)	35 (6.0)	55 (9.4)
50–60	85 (14.6)	70 (12.0)	155 (26.6)
60–70	143 (24.5)	76 (13.0)	219 (37.5)
≥70	90 (15.4)	44 (7.6)	134 (23.0)
Total	346 (59.3)	237 (40.7)	583 (100.0)
P		<0.001	

Table 2: Diabetic retinopathy severity and prevalence classified with the eyeart system

DR severity and prevalence (*n*=583)	Non-DME	DME	Total, *n* (%)
No DR	395	0	395 (67.8)
Mild NPDR	23	4	27 (4.6)
Moderate NPDR	66	18	84 (14.4)
Severe NPDR	31	20	51 (8.7)
PDR	20	6	26 (4.5)
Any DR			188 (32.2)
Referable DR prevalence			165 (28.3)
VTDR prevalence			99 (17.0)

DR=Diabetic retinopathy, NPDR=Nonproliferative diabetic retinopathy, PDR=Proliferative diabetic retinopathy, DME=Diabetic macula edema, VTDR=Vision-threatening diabetic retinopathy

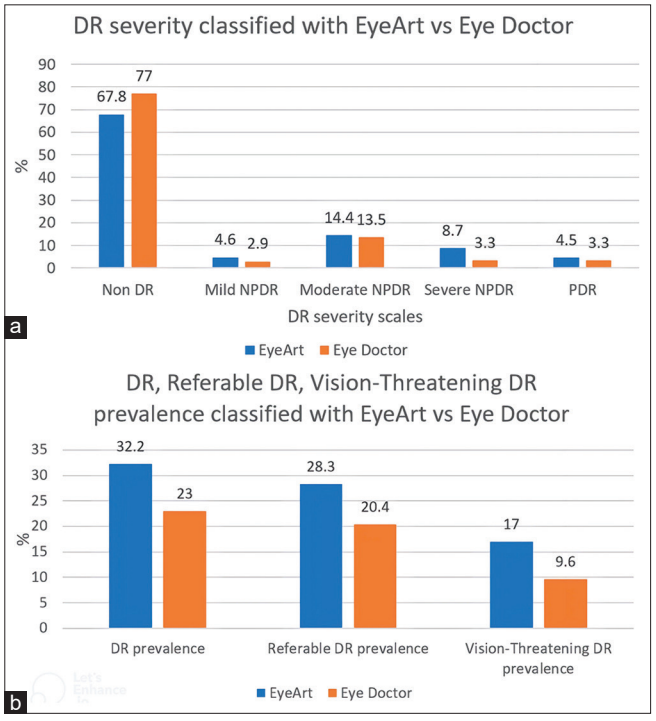

Figure 2: (a) Diabetic retinopathy (DR) severity classified with EyeArt versus eye doctor. (b) DR, referral, vision-threatening DR prevalence classified with EyeArt versus eye doctor

Table 3: Effectiveness of EyeArt artificial intelligence software

Indicators (*n*=583)	DR screening, % (CI 95%)	Referral DR screening, % (CI 95%)	Vision-threatening DR screening% (CI 95%)
TP, FP	128, 57	115, 46	58, 41
FN, TN	8, 390	4, 418	0, 484
Sensitivity	94.1 (90.4–97.8)	96.6 (93.3–99.2)	100 (100–100)
Specificity	87.2 (83.9–90.2)	90.1 (87.3–92.9)	92.2 (89.9–94.3)
PPV	69.2 (62.7–75.7)	71.4 (64.6–78.3)	58.6 (49.5–68.7)
NPV	98.0 (96.5–99.2)	99.1 (98.1–99.8)	100 (100–100)
Accuracy	88.9 (86.1–91.3)	91.4 (89.0–93.7)	93.0 (90.7–95.2)

TP=True positive, FP=False positive, FN=False negative, TN=True negative, PPV=Positive predictive value, NPV=Negative predictive value, CI=Confidence interval

90.4%–97.8%), 87.2% (CI 95%: 83.9–90.2%), and 88.9% (CI 95%: 86.1%–91.3%), respectively [Table 3].

The sensitivity, specificity, and accuracy of EyeArt for referable screening were 96.6% (CI 95%: 93.3%–99.2%), 90.1% (CI 95%: 87.3%–92.9%), and 91.4% (CI 95%: 89.0%–93.7%), respectively [Table 3].

The sensitivity, specificity, and accuracy of EyeArt for vision-threatening DR screening were 100.0% (CI 95%: 100.0%–100.0%), 92.2% (CI 95%: 89.9%–94.3%), and 93.0% (CI 95%: 90.7%–95.2%), respectively [Table 3].

Figure 3a-e shows some digital fundus pictures in the study sample.

Discussion

Demographic characteristics

The mean age in our study was 62 years old, which is the age of retirement in Vietnam, but those at this age can still make a significant contribution to their family and society.

The mean age in our study was similar to that in Singapore,[9] in Thailand,[10] and in the United States.[11] Meanwhile, the mean age of the study in Australia was among young workers (44 years old).[12] In contrast, the mean age in the study in China was high, in the elderly or elderly population (68 years old) [Table 4 and Supplementary materials].[7]

Regarding gender, the participation rate of females in our study was almost 1.5 times higher than that of males, but the participation rate of females was twice as high as that of males in the study in Thailand (female/male ratio was 2).[10] Meanwhile, the participation rate of females was equal to that of males in studies in the United States[11] and in China.[7] On the contrary, the participation rate of females was lower than that of males in the studies in Singapore[9] and in Australia.[12]

The differences in mean age and sex among studies were probably due to different customs and habits, different DR patterns, and different DR screening programs.

Diabetic retinopathy severity classified with artificial intelligence in different studies

Table 5 and Supplementary materials shows that the prevalence of moderate NPDR in all studies was the highest compared with other severity scales. It was

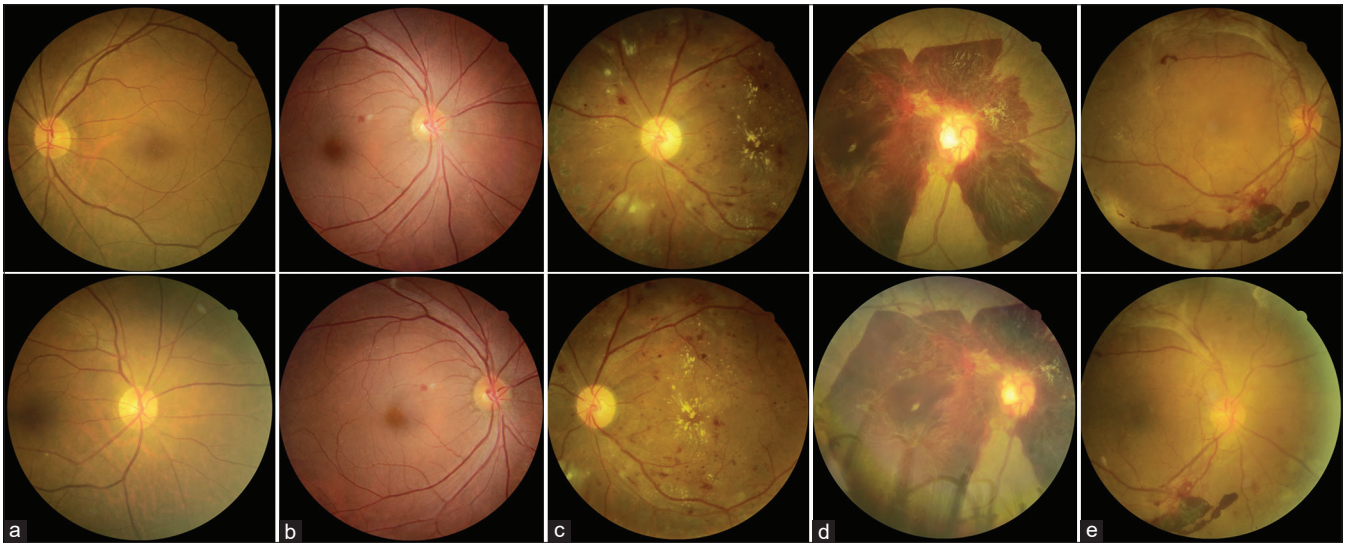

Figure 3: (a) Non-Diabetic retinopathy (Left Eye). Patient: K H Dang Th – 61 years old. Code: EYEM97016. (b) Moderate nonproliferative diabetic retinopathy (NPDR) with hemorrhages and micro-aneurysms (Right Eye). Patient: B Do – 66 years old. Code: EYEM97024. (c) Severe NPDR with hemorrhages, macular edema, and laser spots (Left Eye). Patient: S Huynh – 58 years old. Code: EYEM97047. (d) Proliferative diabetic retinopathy (PDR) with pre-retinal hemorrhages with neovascular vessels (Right Eye). Patient: D H Dao Th – 27 years old. Code: EYEM97021. (e) PDR with preretinal hemorrhages, fibrous proliferation membrane with neovascular vessels (Right Eye). Patient: X M Mai Th – 52 years old. Code: EYEM97080

Table 4: Demographic characteristics of the study sample compared to other studies

Author	Year	Location of study	Number of patient	Mean age	Female: Male ratio
He *et al.*[7]	2019	China	889	68	1.13
Ting *et al.*[9]	2017	Singapore	14,880	60.2	0.83
Raumviboonsuk *et al.*[10]	2019	Thailand	7517	61.13	2.08
Abràmoff *et al.*[11]	2018	America	819	59	1.11
Keel *et al.*[12]	2018	Australia	96	44	0.75
Thanh nguyen van	2022	Vietnam	583	62	1.46

probably a model of DR in the world. The prevalence of moderate NPDR in our study was equal to that of Malavika study using the available digital fundus picture set of EyePACS[8] but was higher than that in the study in China[7] and lower than that in the study in India.[13] The prevalence of mild NPDR in our study was similar to the study in China and in India.[7,13] Note that the prevalence of severe NPDR and PDR in the study of Rajalakshmi[13] in India was too high. It was probably because the study was conducted on people who had a higher prevalence of diabetes and did not have the opportunity to have access to specialized eye-care services. The study of Hsieh *et al*.[14] in Taiwan showed that the prevalence of mild NPDR was the highest and it was much higher than other levels. In other words, in the study, there was a high prevalence of patients coming to the eye doctors at an early stage with only micro-aneurysms. It was possible that the DR screening and referral network was very excellent in Taiwan. It was possible that the author conducted the study on a group of low-risk patients at a particular time or the data collection method was not standardized, leading to the skewed data and causing an increased prevalence of mild NPDR.

Diabetic retinopathy prevalence, referable prevalence, and vision-threatening diabetic retinopathy prevalence in the study sample compared to other studies

The DR prevalence and referable DR prevalence in our study (32.2% and 28.3%) were similar to those in the study of Malavika[8] using 107,001 digital fundus pictures from EyePACS (32.5% and 24.8%). However, the vision-threatening DR prevalence in our study (17.0%) was three times higher than that of Malavika's study (5.1%).[8] Note that the two studies were performed with the same AI system (EyeArt).

The DR prevalence in our study (32.2%) was similar to those in the study of Hsieh *et al*.[14] in Taiwan (34.9%), but the referable DR prevalence in our study (28.3%) was 2.3 times higher than that of Hsieh *et al*.[14] in Taiwan (11.9%). The clear difference was due to the reasons we discussed above.

Compared with other studies, we found that DR prevalence, referable DR prevalence, and vision-threatening DR prevalence in our study were higher than that in the study in Singapore,[9] in Thailand,[10] and in China[15] but ½ times lower than that in the study in India,[13] although the study in India also used the same system as ours (EyeArt) for DR screening [Table 6 and Supplementary materials].

The referable DR prevalence and vision-threatening DR prevalence in our study were quite high. This is a burden for the provincial diabetic eye care network, requiring more investments in the future.

Effectiveness of diabetic retinopathy screening compared among studies performed with the same artificial intelligence system

The sample size in our study (583 patients with 2332 digital fundus pictures) was higher than that in India[13] (296 patients), but lower than that of studies[16,17] using available picture sets of Mesidor-2 and EyePACS. The accuracy in our study was similar to that of

Table 5: Diabetic retinopathy severity was classified with artificial intelligence in different studies

Author (location, year)	Number of patient	Non-DR prevalence (%)	Mild NPDR (%)	Moderate NPDR (%)	Severe NPDR (%)	PDR (%)
He *et al*.[7] (China, 2019)	889	16.3	4.72	9.0	2.59	0.0
Bhaskaranand *et al*.[8] (EyePACS, 2019)	107,001 pictures	67.5	8.2	14.2	2.5	2.6
Raumviboonsuk *et al*.[10] (Thailand, 2019)	7517	87.83		9.8	0.81	1.57
Rajalakshmi *et al*.[13] (India, 2018)	296	68.6	4.7	35.5	10.8	17.6
Hsieh *et al*.[14] (Taiwan, 2021)	1875 pictures	65.12	22.99	8.91	1.23	1.76
Thanh Nguyen Van (Vietnam, 2022)	583	67.8	4.7	14.4	8.7	4.5

NPDR=Nonproliferative diabetic retinopathy, PDR=Proliferative diabetic retinopathy

Table 6: Diabetic retinopathy prevalence, referral diabetic retinopathy prevalence, and vision-threatening diabetic retinopathy prevalence in the study sample compared to other studies

Author	Year	Location of study	Number of patient	DR prevalence (%)	Referal prevalence (%)	VTDR prevalence(%)
Bhaskaranand *et al*.[8]	2019	EyePACS	107,001 pictures	32.5	24.8	5.1
Ting *et al*.[9]	2017	Singapore	14880	-	3.0	0.6
Raumviboonsuk *et al*.[10]	2019	Thailand	7517	-	18.41	8.61
Rajalakshmi *et al*.[13]	2018	India	296	68.6	63.9	28.4
Hsieh *et al*.[14]	2021	Taiwan	1875 pictures	34.88	11.89	-
Zhang *et al*.[15]	2020	China	47,269	28.8	24.4	10.8
Thanh Nguyen Van	2022	Vietnam	583	32.2	28.3	17.0

DR=Diabetic retinopathy, VTDR=Vision-threatening DR

Bhaskaranand,[17] but lower than that of Solanki.[16] The sensitivity in our study was higher than that in the study of Solanki[16] and Bhaskaranand,[17] but lower than that in the study of Rajalakshmi.[13] Meanwhile, the specificity in our study was higher than those of Rajalakshmi[13] in India and those of Solanki[16] and Bhaskaranand[17] using available picture sets of Mesidor-2, EyePACS [Table 7].

The higher sensitivity in our study compared with other studies[16,17] was probably due to our stricter inclusion and exclusion criteria (each patient had enough four digital fundus pictures, excluded all patients with the second DR screening visit, excluded those who experienced treatment with laser photocoagulation or antiVEGF, excluded patients with insufficient information) that excluded digital fundus pictures classified as a positive by eye doctor, but classified as a negative with AI. Of the 101 patients excluded from the study, 83 patients with 332 pictures were identified by eye doctor or EyeArt as unreadable, eight patients with the second visit, three patients with insufficient information, and seven cases with other reasons. Of the eight patients excluded for the second visit, three were classified by eye doctors as having mild NPDR, but classified with EyeArt as not having DR. In other words, this directly reduced the false-negative rate. Therefore, it contributed to the higher sensitivity in our study compared with other studies.

A prospective study by Ip *et al*.[18] showed that fundus image and extent of DR damage can improve following anti-VEGF therapy without significant retinal reperfusion. In addition, many studies found that the classification of DR digital fundus imaging was misleading in patients who had undergone laser photo-coagulation or antiVEGF.[19-21] That was the reason that we excluded patients who had already been treated. Similarly, we only selected patients who came to have their eyes examined at the first visit for the analysis because, on the second visit, we could not determine if these patients had eyes treated or not due to available data. According to us, all these exclusions would not affect the clinical applications of AI-assisted screening on DR in the real world. Furthermore, these exclusions would help more accurately evaluate the sensitivity and specificity of AI in DR screening in community.

Effectiveness of different artificial intelligence systems for diabetic retinopathy screening

The accuracy of DR screening in our study was similar to that in the study of Oliveira[22] and Malerbi,[23] but lower than that of He,[7] Keel,[12] and Hsieh *et al*.[14] The sensitivity and specificity of DR screening in our study (EyeArt, in Vietnam) were similar to those in the study of Hsieh *et al*.[14] (VeriSee™, in Taiwan). The sensitivity of DR screening in our study was lower than that of Oliveira[22] in Portugal and of Malerbi in Brazil,[23] but the specificity was higher than those of two studies. In contrast, the sensitivity in our study was higher, but

Table 7: Sensitivity and specificity in studies implemented with the same artificial intelligence system

Author	Year	Location	Number of patient	Sensitivity	Specificity	AUC
Rajalakshmi *et al*.[13]	2018	India	296	99.30	68.80	-
Solanki *et al*.[16]	2015	Messidor-2	874	93.80	72.20	0.94
Bhaskaranand *et al*.[17]	2016	EyePACS	5084	90.00	63.20	0.88
Thanh Nguyen Van	2022	Vietnam	583	94.1	87.2	0.889[a]

[a]Accuracy. AUC=Area under the curve

Table 8: Sensitivity, and specificity in the different studies with different artificial intelligence systems

Author	Year	Location	Number of patient	Sensitivity	Specificity	AUC
For diabetic retinopathy screening						
He *et al*.[7]	2019	China	889	91.80	98.79	0.946
Abràmoff *et al*.[11]	2018	The United States	819	87.20	90.70	-
Keel *et al*.[12]	2018	Australia	96	92.30	93.70	0.937–0.989
Hsieh *et al*.[14]	2021	Taiwan	1875 pictures	92.2	89.5	0.955
Oliveira *et al*.[22]	2011	Portugal	5386	95.80	63.20	0.849
Malerbi *et al*.[23]	2021	Brazil	824	97.80	61.40	0.890
Thanh Nguyen Van	2022	Vietnam	583	94.1	87.2	0.889[a]
For referable diabetic retinopathy						
Ting *et al*.[9]	2017	Singapore	14,880	90.5	91.6	0.936
Raumviboonsuk *et al*.[10]	2019	Thailand	7517	97.0	96.0	-
Hsieh *et al*.[14]	2021	Taiwan	1875 pictures	89.2	90.1	0.955
Thanh Nguyen Van	2022	Vietnam	583	96.6	90.1	0.914[a]
For vision-threatening diabetic retinopathy						
Ting *et al*.[9]	2017	Singapore	14.880	100.0	91.1	0.958
Thanh Nguyen Van	2022	Vietnam	583	100.0	92.2	0.930[a]

[a]Accuracy. AI=Artificial intelligence, AUC=Area under the curve

the specificity was lower than in the other remaining studies [Table 8].

The accuracy of referable DR screening in our study was lower than that in the study of Hsieh *et al*. in Taiwan[14] and Ting in Singapore.[9] The sensitivity of referable DR screening in our study was similar to that of Raumviboonsuk[10] in Thailand, but higher than that of Hsieh *et al*.[14] in Taiwan and of Ting[9] in Singapore. The specificity of referable DR screening in our study was similar to that of Hsieh *et al*.[14] in Taiwan and of Ting,[9] but lower than that of Raumviboonsuk[10] [Table 8].

The accuracy for vision-threatening DR screening in our study was lower than that in the study of Ting in Singapore.[9] Meanwhile, the sensitivity and specificity of vision-threatening DR screening in our study were similar to those of Ting[9] in Singapore [Table 8].

The study by Van der Heijden *et al*.[24] showed that the validation results were less precise when using real-world data sets compared to those using open-access data sets with the same algorithm. Hsieh *et al*.[14] in Taiwan found that the VeriSee™ system had a better sensitivity than the eye doctor in referable DR screening and data set validation could reduce the false positive rate, which resulted in a higher accuracy in detecting referable DR.

It is more important to use an AI system with high sensitivity for DR screening, but a system with low specificity will risk resulting in a high false-positive rate in real-world practice, which will increase the cost of unnecessary treatment. The sensitivity and specificity of DR screening, referable DR screening, and vision-threatening DR screening in our study were good for screening for DR in community.

Strengths and limitations

In this study, the eye doctors who participated in ICO-guided digital fundus image classification had to undergo training on DR.[2] The high-resolution digital fundus cameras were used by trained technicians. One patient had two digital fundus pictures for each eye, one centered on the macula and another centered on the optic disc. Thus, this study satisfied the demand of Bayer Educational Initiative in 2020 for an effective DR screening program in community.[25]

Another clear strength of the study was that in the condition of not having enough eye doctors, endocrinologists and a lack of specialized equipment in a poor province in Vietnam, the application of AI is effective in DR screening in the community. It decreased training costs, equipment expenditure, and patient transport expenses and helped diabetes have access to hi-tech eye-care services.

The small sample size and retrospective method were the limitations in this study. Although the study conducted consecutive sampling to make it representative of the population, geographical, and visual characteristics of the sample, the study sample was difficult to represent the population due to available data. Under favorable conditions, we wish to conduct a cohort study to evaluate the effectiveness of DR intervention in community in Binh Dinh province in Vietnam.

Conclusion

AI is an effective, easy-to-use tool for screening DR in the community, especially in conditions where there are not enough eye doctors, endocrinologists, and lack of specialized equipment in a poor province like Binh Dinh in Vietnam. Besides, AI will be a useful alternative for eye doctors in diabetic eye care in future. The results of this study will open great opportunities for improving the diabetic eye care network in community and contribute to persuading provincial leaders and policymakers to invest more in the blindness prevention program in the coming years.

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Data availability statement

All data generated or analyzed during this study are included in this published article.

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Nil.

Conflicts of interest

The authors declare that there are no conflicts of interest in this paper.

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Supplementary Materials

LIST OF PATIENTS IN STUDY SAMPLE

Ordinal Number	Patient Code	Age	Ordinal Number	Patient Code	Age
1	EYENUTM25001	59	343	TP1604012	61
2	EYENUTM25002	62	344	TP1604011	67
3	EYENUTM25003	72	345	TP1604010	71
4	EYENUTM25004	77	346	TP1604009	55
5	EYENUTM25005	71	347	TP1604008	49
6	EYENUTM25006	78	348	TP1604007	59
7	EYENUTM25007	68	349	TP1604006	47
8	EYENUTM25008	68	350	TP1604005	73
9	EYENUTM25009	73	351	TP1604004	70
10	EYENUTM250010	41	352	TP1604003	63
11	EYENUTM250011	67	353	TP1604002	43
12	EYENUTM250012	58	354	TP1604001	46
13	EYENUTM250013	67	355	PC1604043	59
14	EYENUTM250014	85	356	PC1604042	83
15	EYENUTM250015	63	357	PC1604041	39
16	EYENUTM250016	63	358	PC1604040	73
17	EYENUTM250017	999	359	PC1604039	56
18	EYENUTM250018	57	360	PC1604038	70
19	EYENUTM250019	63	361	PC1604037	67
20	EYENUTM250020	73	362	PC1604036	71
21	EYENUTM250021	72	363	PC1604035	49
22	EYENUTM250022	66	364	PC1604034	46
23	EYENUTM250023	55	365	PC1604033	58
24	EYENUTM250024	71	366	PC1604032	65
25	EYENUTM250025	58	367	PC1604031	68
26	EYEM97001	87	368	PC1604030	61
27	EYEM97002	62	369	PC1604029	52
28	EYEM97003	71	370	PC1604028	62
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63	EYEM97039	66	405	HAP0007	69
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66	EYEM97042	68	408	HAP0010	53
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76	EYEM97053	69	418	HAP0021	57
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81	EYEM97059	59	423	HAP0026	57
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85	EYEM97064	68	427	HAP0030	59
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95	EYEM97076	61	437	HAP0040	65
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222	EYEM1390113	76	564	EYENUT M 170622002	56
223	EYEM1390114	78	565	EYENUT M 160622001	68
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242	EYEM1390134	80	584	EYENUT M 280722004	62
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245	EYEM1390137	65	587	EYENUT M 260722002	35
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256	DK210701	67	598	EYENUT M 190722003	41
257	DK210703	56	599	EYENUT M 180722001	53
258	DK210704	76	600	EYENUT M 180722002	51
259	DK210705	80	601	EYENUT M 150722001	55
260	DK210706	68	602	EYENUT M 150722002	36
261	DK210707	60	603	EYENUT M 150722004	36
262	DK210708	71	604	EYENUT M 140722002	68
263	DK210709	47	605	EYENUT M 140722003	48
264	DK210710	52	606	EYENUT M 130722001	65
265	DK210711	64	607	EYENUT M 130722002	72
266	DK210715	71	608	EYENUT M 120722001	47
267	DK210717	56	609	EYENUT M 120722002	37
268	DK210719	61	610	EYENUT M 110722001	67
269	DK210720	68	611	EYENUT M 110722002	67
270	DK210722	68	612	EYENUT M 110722003	73
271	DK210723	53	613	EYENUT M 070722001	85
272	DK210724	69	614	EYENUT M 070722002	64
273	DK210725	85	615	EYENUT M 060722001	52
274	DK210726	59	616	EYENUT M 040722001	49
275	PC380904001	69	617	TP082022001	60
276	PC380904002	72	618	TP082022002	59

277	PC380904003	57	619	TP082022003	54
278	PC380904004	53	620	TP082022004	57
279	PC380904005	70	621	TP082022005	49
280	PC380904006	54	622	TP082022006	50
281	PC380904007	62	623	TP082022007	69
282	PC380904008	62	624	TP082022008	50
283	PC380904009	66	625	TP082022009	54
284	PC380904010	65	626	TP082022010	48
285	PC380904011	66	627	TP082022011	63
286	PC380904012	64	628	TP082022012	63
287	PC380904013	69	629	TP082022013	43
288	PC380904014	61	630	TP082022014	64
289	PC380904015	57	631	TP082022015	82
290	PC380904016	70	632	TP082022016	68
291	PC380904017	58	633	TP082022017	61
292	PC380904018	58	634	TP082022018	59
293	PC380904019	79	635	TP082022019	62
294	PC380904020	59	636	TP082022020	63
295	PC380904021	85	637	TP082022021	66
296	PC380904022	58	638	TP082022022	59
297	PC380904023	75	639	TP082022023	50
298	PC380904024	65	640	TP082022024	59
299	PC380904025	71	641	TP082022025	63
300	PC380904026	67	642	TP082022026	72
301	PC380904027	55	643	TP082022027	51
302	PC380904028	80	644	TP082022028	65
303	PC380904029	67	645	TP082022029	67
304	PC380904030	81	646	TP082022030	56
305	PC380904031	58	647	TP082022031	50
306	PC380904032	62	648	TP082022032	44
307	PC380904033	76	649	TP082022033	78
308	PC380904034	61	650	TP082022034	75
309	PC380904035	71	651	TP082022035	48
310	PC380904036	70	652	TP082022036	45
311	PC380904037	64	653	TP082022037	55
312	PC380904038	59	654	TP082022038	55
313	TP1604042	68	655	TP082022039	55
314	TP1604041	46	656	TP082022040	77
315	TP1604040	73	657	TP082022041	54
316	TP1604039	61	658	TP082022042	62
317	TP1604038	66	659	TP082022043	58
318	TP1604037	67	660	TP082022044	74
319	TP1604036	57	661	TP082022045	73
320	TP1604035	46	662	TP082022046	46
321	TP1604034	62	663	TP082022047	62
322	TP1604033	82	664	TP082022048	61
323	TP1604032	58	665	TP082022049	64

324	TP1604031	70	666	TP082022050	58
325	TP1604030	67	667	TP082022051	67
326	TP1604029	68	668	TP082022052	55
327	TP1604028	69	669	TP082022053	61
328	TP1604027	56	670	TP082022054	63
329	TP1604026	71	671	TP082022055	52
330	TP1604025	39	672	TP082022056	54
331	TP1604024	57	673	TP082022057	60
332	TP1604023	67	674	TP082022058	49
333	TP1604022	56	675	PC25082022	79
334	TP1604021	41	676	PC11102022	85
335	TP1604020	74	677	PC10102022	58
336	TP1604019	56	678	PC10082022	16
337	TP1604018	68	679	PC0410202201	57
338	TP1604017	53	680	PC0410202202	66
339	TP1604016	70	681	PC0410202203	73
340	TP1604015	68	682	PC0410202204	65
341	TP1604014	56	683	PC0410202205	90
342	TP1604013	57	684	PC1110202201	999