International Journal of Nursing Practice

WILEY

INTERNATIONAL JOURNAL of NURSING PRACTICE

ORIGINAL RESEARCH OPEN ACCESS

Integrating Nursing–Teleophthalmology Improves Diabetic Retinopathy Screening in Primary Healthcare, Reducing Unnecessary Referrals to Specialist Healthcare

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Received: 30 November 2023 | **Revised:** 6 February 2025 | **Accepted:** 7 April 2025

Keywords: diabetic retinopathy | nursing | portable fundus camera | primary healthcare | teleophthalmology | type 2 diabetes mellitus

ABSTRACT

Aim: This work aimed to evaluate the use of teleophthalmology by a primary healthcare nursing team for the diagnosis and referral for diabetic retinopathy to specialized healthcare in relation to numbers referred for specialized healthcare.

Methods: In this quantitative, cross-sectional service evaluation study, participants with type 2 diabetes mellitus underwent a fundoscopy examination between February and June 2020. Using a portable retinal camera attached to a smartphone, nurses acquired fundus images that were stored on a cloud platform, enabling remote reading by a retinal specialist. The study was conducted at a primary healthcare urban centre on the outskirts of São Paulo, Brazil.

Results: The study enrolled 779 participants, of whom 150 were identified as having diabetic retinopathy present; in another 434, evidence of diabetic retinopathy was absent, and 195 individuals (25%) were classified as having ungradable images. In total, 345 participants were referred for specialized appraisal, 150 of whom due to evidence of diabetic retinopathy and for another 195 participants owing to ungradable images. Thus, more than half of the imaged participants (56%) were not eligible for referral to specialist healthcare and remained treated in primary care.

Conclusions: Nursing–teleophthalmology integration reduced specialized healthcare referral numbers by more than half. This approach contributed to better triage with a more robust evaluation for diabetic retinopathy diagnostic suspicion, reducing unnecessary referral.

1 | Introduction

Diabetic retinopathy (DR) is one of the leading causes of vision impairment in the working-age population (ElSayed et al. 2024). In 2020, worldwide statistics showed that 28.5 million people had loss of visual acuity due to DR. According to estimates, in 2045, around 45 million individuals with diabetes mellitus will be affected by DR (Sun et al. 2022; Teo et al. 2021).

Primary healthcare (PHC) represents the main access of the Brazilian population to public health services via the unified health system. Therefore, PHC is responsible for management of care for noncommunicable chronic diseases such as diabetes mellitus and its complications. In this context, the strategies of care for people living with diabetes mellitus require that a DR screening must be carried out at diagnosis of type 2 diabetes mellitus (T2DM) with annual reassessments, but this interval is

Summary

What is already known about this topic?

- Retinal imaging based on smartphones has been gaining popularity, as an alternative to traditional desktop cameras.
- Teleophthalmology has opened new paths for diabetic retinopathy screening.

What this paper adds?

- Teleophthalmology was shown to be effective in differentiating patients at low risk of diabetic retinopathy, enabling recommendation for treatment to remain in primary healthcare.
- Nursing–ophthalmology integration enabled greater confidence in referrals to specialized care for patients with a more robust indication of diabetic retinopathy.

The implications of this paper:

- Nursing–ophthalmology integration may contribute to more effective referrals and use of public healthcare resources.

individualized in the presence of any retinal pathology. Through the unified health system, the assessment for DR is conducted in specialized healthcare following a referral from PHC. Likewise, for DR treatment, a referral to an ophthalmologist is required after an initial clinical examination (Secretaria de Atenção à Saúde et al. 2013). Even with an integrated health management system, which organizes and controls the flow of patients, scheduling exams, and appointments in specialties takes a long time as specialized healthcare is overburdened. This situation causes a long waiting period, which in turn makes it difficult to monitor and adequately treat DR. Moreover, screening for DR has been shown to be deficient in the face of the growing demand from the rising numbers of the population with newly diagnosed diabetes mellitus (Fernandes et al. 2022).

Cameras for fundus assessment and retinal imaging based on smartphones have been gaining popularity as an alternative to traditional desktop cameras due to their cost-effectiveness and convenience (de Souza et al. 2020; Sung et al. 2023). Telemedicine programmes based on images from portable devices with remote interpretation through teleophthalmology have opened new paths for DR screening and have contributed to greater population coverage. In the same way, artificial intelligence models and deep learning algorithms have been used to diagnose and treat ophthalmic diseases, particularly DR. Thus, a DR intelligent diagnostic system can effectively improve health resource utilization and care in areas with a deficiency of retina specialists (Y.-F. Liu et al. 2023). In this new scenario, the use of teleophthalmology by PHC teams could facilitate DR screening and earlier recognition of individuals at risk of visual loss. The demand for specialized healthcare would be lower and more effective due to prior assessment by primary healthcare, resulting in a greater benefit to patients treated at the public health network.

The purpose of the current study was to evaluate the use of teleophthalmology by a primary healthcare nursing team for the diagnosis and referral for diabetic retinopathy to specialized healthcare in relation to numbers referred for specialized healthcare.

2 | Methods

This quantitative, cross-sectional service evaluation study was conducted at a PHC urban centre on the outskirts of the city of São Paulo, Brazil. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE Statement) checklist was followed to ensure the quality of this observational transversal study report (von Elm et al. 2007). This study was not registered.

2.1 | Sampling and Participants

Convenience sampling was used, considering all individuals with T2DM who were followed-up by family healthcare teams of this PHC unit. Inclusion criteria were individuals with type 2 diabetes mellitus, both genders, any age, and any duration of diabetes mellitus. Exclusion criteria included type 1 diabetes, prior diagnosis of angle-closure glaucoma, total blindness, bedridden individuals, and women with gestational diabetes. Participants were selected and evaluated from February to June 2020.

2.2 | Data Collection

The researchers reviewed health records to collect data about age, duration of diabetes, smoking status, diagnosis of comorbidities such as high blood pressure and dyslipidaemia, and current medications in use. The researchers also extracted the following laboratory test results from the patients' charts: glycated haemoglobin, fasting glucose, urea, creatinine, sodium, potassium, uric acid, total cholesterol, high-density lipoprotein *cholesterol*, low-density lipoprotein cholesterol, triglycerides, and albumin-to-creatinine urinary ratio.

2.3 | The Integrated Nursing–Teleophthalmology Service

Fundoscopy examination was conducted by integrating the nursing–ophthalmology teams with teleophthalmology. In summary, four nurses were responsible for image acquisition after receiving a 4-h in person training, conducted by an ophthalmologist, about the protocol. They were taught how to use the portable retinal camera (Eyer. Phelcom Technologies, São Carlos, Brazil), apply the tropicamide eye drops (Mydriacyl Solution, 10 mg/mL, Novartis Biociências S.A.) and know the correct waiting time for its action and potential side effects. Continuous remote feedback was given by the specialist as images were interpreted. The learning curve of image acquisition was evaluated according to the number of patients whose images allowed a clinical decision on the day of examination. From the seventh day onward, the rate of images that allowed a clinical decision was maintained above 80%. Examination duration per patient median 2 min (interquartile range (IQR): 1–3 min). The applicability and effectiveness of this protocol have been previously tested and published elsewhere (Queiroz et al. 2020).

2.3.1 | The Examination Protocol

Participants were advised to bring a companion on the day of the exam. Upon arriving at the PHC centre, participants remained seated in a private room, resting for around 10 min, and blood pressure and capillary blood glucose were measured after this interval. Next, the nurse responsible for the examination administered one drop of the tropicamide eye drops (Mydriacyl Solution) into each eye, with another rest period of 5–10 min for the medication to take effect. Next, the fundoscopy examination was carried out using a portable retinal camera. For proper retinal analysis, two images of the posterior segment were captured, one centred on the fovea and another centred on the optic disc of each eye. The images were then stored on the EyerCloud platform (Phelcom Technologies, São Carlos, Brazil), enabling remote reading by a retina specialist. Each eye was classified regarding diabetic retinopathy severity and the presence of macular oedema according to the International Diabetic Retinopathy Classification (IDRC), after evaluation of macula-centred and optic-disc centred images (Wilkinson et al. 2003). The classification was given to each patient according to the most severely affected eye.

Ungradable images were categorized into two groups. The first category referred to images with suboptimal capture technique: i.e., images out of focus, insufficient, and/or incorrect fields captured, or artefacts present from the camera lens. The second group of ungradable images encompassed individual characteristics such as limited pupil dilation, motion blur, or media opacities.

Fundoscopy reports were provided to the family health teams for necessary referrals. All participants with DR, as well as participants with ungradable images, and those with other detected ocular anomalies were referred to specialized healthcare.

2.4 | Data Analysis

Statistical analyses were conducted using the SAS/STAT software. The sample had a nonparametric pattern in the Shapiro–Wilk test. Hence, the nonparametric ANOVA test was applied for variables that reached statistical significance in the Kruskal–Wallis's test and the pairwise two-sided multiple comparison analysis to identify differences among groups. A p value of <0.05 was considered statistically significant.

3 | Results

The study enrolled 779 participants; 150 were diagnosed with DR present, 434 with DR absent, and the retina could not be visualized in 195 individuals (25%), who were grouped as ungradable images. For 75 of these participants (38.5%), the reason for ungradable images was ocular media opacities, which generally represents cataracts in this population. In the remaining 120 individuals of this group DR classification was not possible due to: inadequate technique ($n=6$; 5%), inappropriate photographic framing ($n=44$; 36.7%), insufficient mydriasis ($n=1$; 1%) and other reasons ($n=7$; 6%) (Figure 1). All photographs ($n=779$) of the fundus and images appraised by a retina specialist took place during a period of less than 6 months, at the beginning of the COVID-19 pandemic.

Nursing–ophthalmology integration with teleophthalmology enabled the retina analysis in 584 participants, i.e., 75% of the population evaluated in the present study. One hundred and fifty participants had signs of DR in teleophthalmology assessment, which represents a prevalence of 19.3% in the target population ($n=779$). In total, 345 participants were referred for specialized appraisal, 150 of whom due to evidence that DR was present and another 195 participants owing to ungradable images. Therefore, over half of the participants (56%) were not eligible for evaluation by an ophthalmologist and remained being treated in primary care.

Clinical and demographic characteristics of participants are described in Table 1. To analyse the variables of interest, the group with ungradable images was composed of participants with media opacity and insufficient mydriasis ($n=76$). Participants with ungradable images were older than those with DR absent ($p<0.001$) and DR present ($p<0.001$). However, age was not statistically different between the groups with DR absent and DR present ($p=0.178$). Diabetes mellitus duration reached statistical difference in the comparison between groups with DR absent and DR present ($p=0.003$); however, diabetes mellitus duration was not significantly different between the groups with DR absent and the ungradable image group ($p=0.99$), nor between the groups with DR present and ungradable images ($p=0.118$). Glycated haemoglobin results showed statistically significant differences only between the groups with DR absent and DR present ($p=0.041$). The remaining variables (fasting glucose, systolic and diastolic blood pressure, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, creatinine, and albumin-to-creatinine urinary ratio) did not reach statistical significance in comparisons between participants stratified by ophthalmological diagnosis.

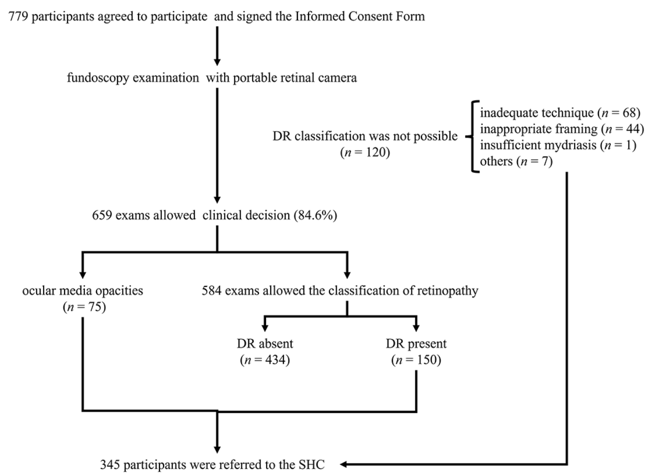

FIGURE 1 | Schematic flowchart of the study. Legend: DR: diabetic retinopathy; *n*: number of participants; SHC: in specialized healthcare.

TABLE 1 | Clinical and demographic variables of participants according to ophthalmological diagnosis.

	Ungradable images ($n = 76$)			DR present ($n = 150$)			DR absent ($n = 434$)		
	Mdn	**LQ**	**UQ**	**Mdn**	**LQ**	**UQ**	**Mdn**	**LQ**	**UQ**
Age (y)	79	72	84	68.5	60	75	67	59	73
Gender M/F (%)		34/66			44/56			40/60	
DM duration (y)	8	4	17	10	6	16	10	5	14
Glycemia (mg/dL)	115	103	162	125	89.5	177.5	122	104	157
A1c (%)	7.0	6.1	8.6	7.8	6.4	10	6.8	6.2	8.3
SBP (mmHg)	140	130	158	140	130	150	140	122	150
DBP (mmHg)	86	80	92	80.5	78	91	81.5	79	90
HDLc (mg/dL)	49	38	59	45	38	55	44	37	55
LDLc (mg/dL)	92.5	70	116	109	92	138	113	90	134
Creatinine (mg/dL)	0.95	0.75	1.05	0.9	0.7	1.0	0.9	0.7	1.1
ACR (mg/g de cr ur)	13.1	9.7	39.7	15.5	5.7	28.5	10.4	5.6	29

Note: Data presented as Mdn: median; LQ: lower quartile; UQ: upper quartile; *n*: number of participants; DR: diabetic retinopathy; y: years; M: male; F: female; DM: diabetes mellitus; A1c: glycated haemoglobin; SBP: systolic blood pressure; DBP: diastolic blood pressure; HDLc: high-density lipoprotein cholesterol; LDLc: low-density lipoprotein cholesterol; ACR: albumin: creatinine urinary ratio; cr: creatinine; ur: urinary.

The researchers were able to track 247 (71.6%) referrals to the ophthalmology clinic within specialized healthcare. Two hundred patients attended an appointment, 14 died during the follow-up period, 13 missed the specialist office visit, and another 5 withdrew from treatment. Ten participants were already under specialist care, four changed neighbourhoods and were no longer followed-up at the PHC centre, and one was diagnosed with total blindness and discharged. The median waiting time for an ophthalmologist appointment was180 days (IQR: 122–203 days).

4 | Discussion

Teleophthalmology enabled the retinal evaluation of 75% of participants recruited in primary healthcare. Studies comparing digital fundus photography with seven-field imaging, as used in Early Treatment DR Study or mydriatic ophthalmoscopy, identified reasonable diagnostic test accuracy to DR screening telemedicine programmes (Horton et al. 2020; Piyasena et al. 2019). Pharmacological pupil dilation has been shown to increase the sensitivity and specificity in detecting DR by nonstereoscopic retinal photographs (Horton et al. 2020; Salongcay et al. 2022). Furthermore, the performance of a handheld fundus camera (Eyer) used in the present study was compared with standard tabletop fundus cameras for DR screening. The authors described agreement between devices for DR classification of 73.18%, with a weighted kappa of 0.808 (almost perfect) (de Oliveira et al. 2023).

In the current research, registered nurses were responsible for capturing retinal images using a portable retinal camera whereas remote image reading was performed by a retinal specialist. All 779 retina photographs were taken in a period of less than 6 months and in a critical period near the start of the COVID-19 pandemic. DR prevalence reached 19.3% in this population, and its presence was associated with higher glycated haemoglobin values and a longer duration of diabetes. The estimated prevalence of DR in South and Central Americas is 13.4%, lower than the global average of 34.6% (Teo et al. 2021). In Brazil, there are few studies that have aimed to establish the national prevalence of DR. Often, the information comes from regional studies and specific populations followed in the public health system or in local reference services. This situation is explained by a geographically heterogeneous distribution of ophthalmologists, and lack of ophthalmologists in the public sector, in addition to various barriers faced by patients in relation to receiving proper healthcare including the deficiency of education and limited awareness about diabetes and its complications (Fernandes et al. 2022). Despite the high heterogeneity observed in systematic reviews of prevalence, Chagas et al. found a DR prevalence of 36.3% among Brazilian individuals with diabetes (Chagas et al. 2023). In turn, an investigation carried out in the Brazilian Public Health System Information Database found an overall screening coverage rate of only 22% estimated for DR (Fernandes et al. 2022).

Some risk factors have been well established to be associated with DR, such as diabetes duration, glycated haemoglobin values greater than 7%, arterial hypertension, dyslipidaemia and albuminuria (Ghamdi 2020; Nilay and Thool 2022). In this study, risk factors involved in the progression and severity of retinal lesions, such as poor metabolic control and a longer duration of diabetes, were significantly more frequent among individuals with DR present.

In sum, the prevalence found in the current research was consistent with the results of other studies employing similar retinal analysis technology, and with those conducted with regional populations (Malerbi, Andrade, et al. 2022; Malerbi, Mendes, et al. 2022; Rosses et al. 2017).

According to the guidelines, individuals with T2DM should undergo DR fundoscopy at the time of diagnosis, with annual or individual reassessment in the presence of alterations. Nonetheless, in PHC the flow for DR screening is complex since all patients with diabetes mellitus should be referred to specialized healthcare for an appointment with an ophthalmologist. After this first step, if treatment is required, the patient will be referred to a retinal specialist (Ferreira et al. 2018). In recent years, the integration of primary care physicians, nurses, or even undergraduate student ophthalmologists, by teleophthalmology has be shown to be a valuable way to increase DR screening coverage (Fernández-Gutiérrez et al. 2023; Gobbi et al. 2022; Rodríguez Villa et al. 2018). In the current study, all 779 individuals should have been referred to specialized healthcare for an ophthalmologic evaluation. However, the initial assessment via teleophthalmology allowed the triaging of participants regarding DR and the presence of media opacities, which are more precise indications for specialist evaluation. As a result, this procedure reduced specialized healthcare referral demand to less than half the numbers of participants (44%). Consequently, this approach could provide better use of resources by avoiding unnecessary patient appointments, with such collaborations supporting the sustainability of healthcare systems around the world, and especially in countries with a complex triage flow like Brazil.

Attendance rates to referrals centres are variable among studies that used telemedicine in the initial assessment of DR. In a retrospective study conducted in primary care clinics of a large county hospital in the USA, of 408 patients detected with vision-threatening DR, only 5% completed the first ophthalmology appointment within the recommended referral interval, 15% within twice the recommended interval, and another 51% within 1 year of DR screening (Bresnick et al. 2020). According to Zhu et al., 46.1% of 3362 participants with vision-threatening DR did not complete the referral to specialist healthcare, and older age and lower education levels were significantly associated with incomplete referrals (Zhu et al. 2020). Other studies have examined patient behaviours after telemedicine screening and found between 49% and 70% of patients compliant with ophthalmology referral appointments (J. Liu et al. 2021; Mathenge et al. 2022; Song et al. 2022; Stebbins et al. 2021). Ferreira et al. also estimated the average time between ophthalmological indication and the referred centre office visit. The waiting time for the first visit with specialist healthcare was 133.2 (113.1) days. Where surgical treatments were indicated, a further 55.5 (55.4) days were added until the date scheduled for the procedure (Ferreira et al. 2018).

The researchers successfully traced 71.6% of the participants referred to specialized healthcare clinics. Two hundred individuals completed the assessment and received appropriate treatment, and the effectiveness rate for treatment access was 58% for the population enrolled in the current study. The waiting time for the initial appointment was 162.8 ± 54 days, higher than previous Brazilian studies, which may point to an overload of the specialized healthcare service referred to (Ferreira et al. 2018). Teleophthalmology support can contribute to better triage, bringing down unnecessary referrals, thus guaranteeing specialized care to patients with a more robust diagnostic suspicion. The initial challenge is to link PHC to the specialized treatment facilities. However, as mentioned by Bresnick et al., whilst retinopathy screening is the first step for preventing visual loss associated with DR, it must also include patient engagement and monitoring ophthalmic referrals and management (Bresnick et al. 2020). It is also essential to improve patients' adherence to all those steps.

Undoubtedly, these results provide valuable insights into how proper training of nurses to capture retinal images can significantly reduce the number of ungradable images caused by operator-related issues, adding value to the sustainability of the healthcare system. This study demonstrated an image rate that allowed a clinical decision above 80%, and the effectiveness rate for treatment access of 58% for the population enrolled in this study.

4.1 | Strengths and Limitations of the Study

The main strengths of the present study are that all participants were followed in PHC in a large city, and data from this specific group in the literature are scarce. Recruiting participants from a single centre promotes greater homogeneity concerning sociodemographic variables, access to healthcare, laboratory testing, and diabetes control; and demonstrates the feasibility of care flow. The current study was limited by selecting only individuals with type 2 diabetes, which did not allow extrapolation of the results to the population with type 1 diabetes. Fundus photographs were evaluated by only one retinal expert. In addition, recruiting from a single PHC, it should not be assumed that the prevalence of DR would be the same in all PHC centres.

5 | Conclusion

The use of a portable fundus camera attached to a smartphone by the nursing team proved to be a viable strategy for DR screening in primary healthcare. Teleophthalmology showed to be effective in differentiating patients at low risk of DR, and with a recommendation for remaining in primary healthcare, from those at higher risk requiring specialist follow-up. Furthermore, the nursing–ophthalmology integration provided by the technology use can contribute to a better management and application of public resources.

Author Contributions

Jacira Xavier de Carvalho: investigation, data curation, project administration. **Fernando K. Malerbi:** conceptualization, validation, resources, writing – review and editing. **Mozania Reis de Matos:** investigation. **Silvia Ferreira Bortoto:** investigation. **Cristiane das Graças Dias Cavalcante:** investigation. **Elenilda Almeida Silva Andrade:** investigation. **Gabriela Bonfim Vieira:** investigation. **Márcia Silva Queiroz:** conceptualization, methodology, validation, formal analysis, writing – original draft, supervision.

Acknowledgements

The authors thank Phelcom Technologies, São Carlos, Brazil, for making the smartphone-based hand-held device available and the EyerCloud platform.

Ethics Statement

The study was approved by the Ethics and Research Committee of *Universidade Nove de Julho - UNINOVE*, and by the Ethics and Research Committee of the Sao Paulo Health Department (#81249417.1.3001.0086). All participants read and signed the Informed Consent Form.

Conflicts of Interest

FKM is a Phelcom Technologies medical consultant. All other authors declare that they have no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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