

## Various models for diabetic retinopathy screening that can be applied to India

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The increased burden of diabetes in India has resulted in an increase in the complications of diabetes including sight-threatening diabetic retinopathy (DR). Visual impairment and blindness due to DR can be prevented by early detection and management of sight-threatening DR. Life-long evaluation by repetitive retinal screening of people with diabetes is an essential strategy as DR has an asymptomatic presentation. Fundus examination by trained ophthalmologists and fundus photography are established modes of screening. Various modes of opportunistic screening have been followed in India. Hospital-based screening (diabetes care/eye care) and community-based screening are the common modes. Tele-ophthalmology programs based on retinal imaging, remote interpretation, and grading of DR by trained graders/ophthalmologists have facilitated greater coverage of DR screening and enabled timely referral of those with sight-threatening DR. DR screening programs use nonmydriatic or mydriatic fundus cameras for retinal photography. Hand-held/smartphone-based fundus cameras that are portable, less expensive, and easy to use in remote places are gaining popularity. Good retinal image quality and accurate diagnosis play an important role in reducing unnecessary referrals. Recent advances like nonmydriatic ultrawide field fundus photography can be used for DR screening, though likely to be more expensive. The advent of artificial intelligence and deep learning has raised the possibility of automated detection of DR. Efforts to increase the awareness regarding DR is essential to ensure compliance to regular follow-up. Cost-effective sustainable models will ensure systematic nation-wide DR screening in the country.

**Key words:** Diabetic retinopathy, screening models, tele-ophthalmology

Diabetes is one of the most prevalent noncommunicable diseases (NCDs) imposing a significant impact on the global healthcare systems.<sup>[1]</sup> Diabetic retinopathy (DR), the most common microvascular complication of diabetes, is one of the important causes of preventable blindness globally.<sup>[2]</sup> Proliferative DR and diabetic macular edema are two main sight-threatening components of DR (STDR). Screening for DR is essential as individuals with DR are often asymptomatic during the earlier stages.<sup>[2]</sup> Early detection of DR by regular screening can help in slowing the progression of any DR to STDR with good control of modifiable risk factors like hyperglycemia, hypertension, and treatment of dyslipidemia.<sup>[3]</sup> Timely intervention can reduce the risk of severe visual loss by 90% according to Early Treatment Diabetic Retinopathy Study (ETDRS).<sup>[4]</sup>

Although the prevalence and incidence of all stages of DR has been declining in the recent years, thanks to improved diabetes control, the crude prevalence of visual impairment, and blindness caused by DR worldwide increased between 1990 and 2015,<sup>[5]</sup> largely because of the increasing prevalence

of type 2 diabetes (T2D), especially in the low-income and middle-income countries (LMIC). Early detection of DR/STDR and timely management of STDR can help preserve normal vision in people with diabetes.

The International Diabetes Federation estimated that, in 2019, there were over 77 million people with diabetes in India and that the numbers are expected to increase to 101 million by 2030 with a large number of people having undiagnosed diabetes.<sup>[6]</sup> The fact that diabetes is frequently not diagnosed until the complications sets in, and that more than half of the individuals with diabetes remain undiagnosed is quite alarming.<sup>[7]</sup> Even more worrisome is the fact that over a third of people with diabetes have never undergone an eye examination.<sup>[8]</sup> Various studies have shown that about one-fifth of people with diabetes in India have some form of DR.<sup>[9]</sup>

The National Program for Control of Blindness recommends opportunistic screening for early detection of DR.<sup>[8]</sup> Every opportunity of contact should be utilized for screening people with diabetes with and without DR to enable early diagnosis and appropriate referral. Currently, there are many opportunistic screening programs being conducted by

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nongovernment organizations (NGOs), private diabetes care providers, or eye care facilities in our country.<sup>[10-12]</sup> With a large number of people with diabetes to be screened repetitively, no single DR screening model will be suitable to implement across a diverse country like India. In this review article, we shall be looking at various screening models that are available or models that can be applied to India to enable nation-wide screening for DR.

## Screening for DR

Screening is a process of identification of unrecognized diseases or disorders by tests in apparently healthy asymptomatic individuals. DR screening meets the World Health Organization (WHO) criteria for screening programs<sup>[13]</sup>: (i) the condition must be a current important public health concern, (ii) the condition must have a recognizable early/latent stage, (iii) the screening protocol should be easily acceptable to the public as well as health care professionals, (iv) must have effective well-accepted treatment options, and (v) cost of early diagnosis and management should be considered in relation to total health care expenditure, as well as the consequence for leaving the disease untreated.<sup>[13]</sup> As DR is an asymptomatic condition that can progress to irreversible vision loss without timely treatment, it is a candidate condition that meets the above criteria for a national screening program.<sup>[10]</sup>

Current DR screening guidelines recommend the first retinal examination in individuals with type 1 diabetes within 5 years after diagnosis and annually thereafter.<sup>[14]</sup> People with T2D should have their first retinal examination at the time of diagnosis of diabetes and then annually thereafter.<sup>[2,14]</sup> More frequent retinal assessment is advised based on increasing severity of DR. Individuals with diabetes during pregnancy are at increased risk for progression of DR. Retinal examination prior to conception and at 6 weeks of pregnancy is essential for assessment of the stage of DR to advise regarding suitable follow-up/DR management.<sup>[14]</sup>

Methods of screening for DR include direct and indirect ophthalmoscopy, stereoscopic seven field fundus photography, nonmydriatic, or mydriatic digital retinal color fundus photography.<sup>[2]</sup> **Table 1** shows the various devices that can be used for screening of DR. The gold standard for the detection of DR consists of seven standard field 30° stereoscopic fundus photography developed for classification and grading of DR by the ETDRS group.<sup>[15]</sup> Mydriatic fundus photography has been accepted to be equivalent or superior to ophthalmoscopic examination for DR detection and proved to be the most sensitive screening test for STDR.<sup>[16,17]</sup> Fundus photography has become globally accepted as the mode of DR screening with a wide variety of retinal imaging devices being available.<sup>[18,19]</sup> Majority of the present fundus cameras have high resolution which exceeds the 2–3 megapixel resolution required to display a single microaneurysm.<sup>[18]</sup> With good image quality, the retinal photographs can easily be graded by trained image graders/trained optometrists/ophthalmologists using the ETDRS classification or the International Clinical Classification of Diabetic Retinopathy classification.<sup>[15,20]</sup> Retinal color photography has valuable roles in screening, detection/documentation of DR lesions, counselling the patient, monitoring the progression of DR, as well as the response to treatment.<sup>[19]</sup> With large number of people with diabetes to be

screened regularly, manual grading of fundus photographs by trained graders may not be a feasible option. Automated DR detection through artificial intelligence (AI)/deep learning algorithms can enable instant diagnosis and be valuable for remote DR screening and telemedicine.<sup>[21]</sup> However, they need to be tested more in real-time field settings before they can be used widely.

Efforts to increase screening for DR should be accompanied by efforts to increase the awareness, education regarding diabetes, its complications, especially DR to ensure compliance to regular follow-up.<sup>[22]</sup> Studies have shown that implementation of systematic DR screening programs at a national level in some developed countries have reduced the visual impairment due to DR.<sup>[23]</sup> However, resources for nationwide screening programs are scarce in LMIC like India. **Table 2** shows the various models of DR screening being followed as well as those that can be applied in India. The different models highlighted in Table 2 are discussed in detail below.

### Hospital-based DR screening model

#### *Physician clinics*

General physicians who are trained in using a direct ophthalmoscope can examine the fundus of people with diabetes who come to their clinics. Physicians are often the first contact for people with diabetes. Many physicians and diabetologists across India have undergone hands on training in fundus examination/fundus photography through the Public Health Foundation of India (PHFI) Certificate Course of Diabetic Retinopathy for capacity building of physicians and ophthalmologists.<sup>[24]</sup> Physicians may often fear to dilate the patients for fundus examination. Unfortunately without dilatation, the physician/diabetologist would be able to just view the optic disc or the macula and in older patients, examination would be challenging due to senile cataract. Being asymptomatic, people with diabetes often tend to refuse a dilated fundus examination due to lack of awareness. Direct ophthalmoscopy fundus examination requires coming in close proximity to the patient, hence may be challenging, especially with the ongoing Covid-19 pandemic. Second physicians examining a large number of patients daily may not be able to devote extra time for a detailed fundus examination or grade retinopathy.

DR screening and interreferral can be done in polyclinics where the diabetologists can refer people with diabetes to the ophthalmologists working in the same hospital for fundus examination/further management and vice versa; the ophthalmologists can refer individuals with DR to the diabetologist for glycemic control.

#### *Screening at noncommunicable disease (NCD) clinics*

A comprehensive program was launched in public health NCD clinics in 10 districts across India for detection of eye complications among people with diabetes in 2016–2018 through the PHFI Queen Elizabeth Diamond Jubilee Trust DR project.<sup>[11]</sup> A national task force was constituted to oversee policy formulation and provide strategic direction for the program. Mentoring partners (eye care and diabetic care) to hand-hold the district health system were identified. State and district coordination committees were established to monitor the progress of the program. Capacity building of the core health personnel and installation of equipment was carried out in the 10 district hospitals. Using nonmydriatic

**Table 1: Devices for DR screening in India**

Device	Advantages	Disadvantages
Direct Ophthalmoscope	Relatively inexpensive: easy to carry and easy to use	Needs dilatation for better view; smaller field of view, lower sensitivity, and close contact risk
Indirect Ophthalmoscope	Wider field of view, relatively inexpensive	Mydriasis mandatory, needs training for use/used only by trained ophthalmologists
Slit-lamp biomicroscopy with contact (three mirror lens) or noncontact lens (78D/90D lens)	Wider field of view, good sensitivity	Mydriasis mandatory, needs training for use/use only by trained ophthalmologists
Nonmydriatic camera Without dilatation	40-45° field of view; easy to use with minimal training; undilated pupils; can be transported to the community for remote and rural screening in mobile units; linked to the system for electronic data storage	Poor image quality especially for older people with media opacities like cataract Single field image may miss lesions in other field (at least two fields (disc centered and macula centered for each eye to be taken)
With dilatation	Better image quality, imaging of more fields possible. Useful for telemedicine	Good internet connection needed for image transfer for remote grading by trained graders/ophthalmologists
Handheld fundus camera/ smartphone-based fundus camera	Easy to handle, portable, less expensive; can be charged and then used without electrical power connection; can be connected with WiFi for use in tele-ophthalmology/rural screening; can have AI-integrated automated system	Image quality may be inferior without mydriasis especially for older people with cataract. Mydriasis improves gradability Good internet connection needed for transfer of images for remote grading
Conventional desktop camera	Larger field of view (50°); excellent resolution: seven field stereo photography is possible: easy to use with training by optometrists; good image quality; used especially in the eye hospitals	Mydriasis required, expensive
Ultrawide field fundus camera (Scanning Laser Ophthalmoscope)	Very wide field of view up to 200° without dilatation; can detect peripheral DR lesions also	Very expensive, cannot be used for mass screening in India unless the cost gets reduced

**Table 2: Various screening models for diabetic retinopathy**

	Screening model	Techniques
A	Hospital-based screening model Screening by Physicians/Diabetologists (Complications screening by diabetologist) a. Primary Physician clinic b. Secondary Care hospital/multispeciality Polyclinics c. Tertiary Care hospitals/Diabetology/ Endocrinology clinics d. Ophthalmologist-based screening tertiary care eye facilities	Examination by physician with direct ophthalmoscope 1. Referral to trained ophthalmologist for fundus examination or 2. Use of nonmydriatic fundus camera for retinal imaging by trained eye technician/optometrists 1. Referral to retina specialist for fundus examination and management 2. Fundus photography - Grading of fundus photographs by trained graders/ophthalmologist and/or artificial intelligence (AI) 1. Fundus examination by trained ophthalmologist with indirect ophthalmoscopy or slit-lamp biomicroscopy 2. Fundus photography - Grading of fundus photographs by trained optometrists/ophthalmologists
B	Community-based screening model Diabetes screening programs Rural outreach programs At pharmacies/optical shops Risk-based screening	Use of nonmydriatic fundus camera for retinal imaging by trained eye technician and images graded by trained graders or trained ophthalmologists
C	Teleophthalmology screening model	Use of nonmydriatic fundus camera for retinal imaging by trained eye technician and images graded by trained graders or trained ophthalmologists or with use of artificial intelligence

cameras, 66,455 individuals with diabetes were screened in these clinics; 10,765 (16.2%) individuals were found to have DR of which 4974 (7.5%) had STDR. In total, 80.8% of individuals with STDR were treated. Typically, 6,720 people with DM (10.1% of those who were initially screened) returned

for the next annual assessment. The study reported that there was a sevenfold increase in DR screening through this initiative.<sup>[11]</sup> The project showed that a collaborative approach can enable successful DR detection and management at district and subdistrict levels.

### *Dispensaries and hospitals*

Secondary care centers/hospitals that can invest in fundus cameras employ trained eye technicians for fundus imaging to be carried out for screening people with diabetes visiting their hospitals. Individuals with diabetes ( $n = 236$ ), who visited various dispensaries of the Municipal Corporation, Mumbai, were screened for DR using a smartphone-based, nonmydriatic retinal camera by a health care worker.<sup>[25]</sup> Three fundus fields were photographed in each eye. The images were graded by an ophthalmologist and an offline AI system. The sensitivity of the offline AI system in diagnosing referable DR was 100%, and the specificity was 88.4%.<sup>[25]</sup> The study showed that the use of offline automated algorithm integrated with low-cost fundus camera can possibly be a scalable mode of DR screening in India, especially for remote areas.

### *Tertiary care diabetes centers*

Screening for complications of diabetes including DR is feasible particularly in the tertiary diabetes care centers as patients with poor glycemic control visit these centers and annual follow-up visit is possible in such Institutions.<sup>[26]</sup> Very often individuals with diabetes may not visit the ophthalmologist for DR screening due to lack of awareness that eyes can be affected in diabetes. Hence, the role of the diabetologists and diabetes educators in increasing awareness among the people with diabetes regarding retinal examination is very crucial. DR screening in individuals with type 1 diabetes is also possibly only in large diabetes care facilities.<sup>[12]</sup>

### *Eye hospitals/multispecialty eye care facilities*

Trained ophthalmologists screen for DR by performing slit-lamp biomicroscopy with 78 D/90 D lens and indirect ophthalmoscopy for entire retinal examination after pupil dilatation (mydriasis). As the clinical course of DR has a long asymptomatic phase, individuals with diabetes do not visit the retina specialist until they are symptomatic due to STDR. Tertiary eye care facilities with vitreo-retina clinics provide the expertise in fundus examination and further management. All people with diabetes, visiting eye hospitals for a general eye check-up/refraction, can be referred to the retina clinic for good quality retinal imaging after mydriasis for accurate DR diagnosis and appropriate management of STDR. However, the limited number of trained retina specialists and eye hospitals is a barrier for the wide implementation of such screening. To decrease the burden of ophthalmologists, fellowship courses for capacity building of optometrists have been conducted and 870 optometrists were trained/certified in grading DR and STDR.<sup>[27]</sup>

To conclude, hospital-based screening models are targeted and enable opportunistic screening and DR detection in people with known diabetes. However, those who are asymptomatic with undiagnosed diabetes may not visit the hospital and may have undetected DR.

### **Community-based DR screening model**

In LMIC like India, where tertiary diabetes care facilities or eye care hospitals alone may not be sufficient to cater to the needs of the large numbers of people with diabetes to be screened. Though many local population-based screening and awareness programs have been conducted across the nation through camps, there is no systematic approach for screening to meet the standards of national screening programs available in some western countries.<sup>[23]</sup>

In India, to ensure every person with STDR is detected before vision loss occurs, we need to strike a balance between the gold standard and practically acceptable protocols to detect referable DR, as we have to screen a large number of people with diabetes.<sup>[28]</sup> Many individuals with diabetes do not undergo regular fundus examination due to lack of awareness about DR, financial constraints, and limited access to specialized ophthalmic care. In this scenario, community screening of DR will be beneficial to such people, help in increasing awareness, and improving compliance to established DR management and follow-up protocols.<sup>[29]</sup> Steps to improve awareness about DR among individuals with diabetes, their families, the public, and the healthcare professionals are essential to enable early detection of DR.<sup>[22,24]</sup>

The main models of community level screening are diabetes screening and DR screening programs, rural outreach programs and screening in health care services like pharmacies, optical shops, etc. A major role can be played by community participation and improving the health seeking behavior in people with diabetes.

### *DR screening as a part of diabetes screening programs*

Screening of the general population for diabetes is the first step in DR screening. These diabetes screening programs help identify people with diabetes and screen those with diabetes for DR, educate them about DR, recommend appropriate referrals to nearby hospitals, and help clinicians and epidemiologists to assess the burden and establish suitable diabetes and DR care policies.

Numerous diabetes and DR screening programs are organized each year by a variety of NGOs, diabetes care, and eye care centers on November 14<sup>th</sup>, World Diabetes Day in India. Such programs assist in the detection of diabetes in adults through the Indian Diabetes Risk Score,<sup>[30]</sup> a validated risk score that identifies people who are at risk for development of T2D and a random blood sugar test using a finger prick (glucometer). Those people who attend these screening programs with known diabetes or newly diagnosed diabetes undergo visual acuity testing and fundus examination/retinal photography as a part of DR screening. These screening programs also have posters on importance of blood sugar control, life style modification, regular retinal check-up, and awareness talks/lectures by diabetologists, ophthalmologists, dieticians, and diabetes educators. Such screening programs are also conducted on World Sight Day also by various eye NGOs. The All India Ophthalmological Society Diabetic Retinopathy Eye Screening Study 2014 by Gadkari *et al.*<sup>[31]</sup> that was conducted during the World Diabetes day/Week in 2014 reported the prevalence of DR in India as 21.7%.

In community screening programs conducted in three districts in south Tamil Nadu over a year to screen for diabetes and DR in 2001, 3,949 individuals with diabetes were screened for DR by ophthalmologists using indirect ophthalmoscopy.<sup>[10]</sup> DR was detected in one-fifth of people screened. This turned out to be an affordable method of screening at a time when fundus cameras were very expensive to use in these screening programs. Nowadays, corporate screening programs are also carried out in offices, banks, and IT companies where stress at work and lack of physical activity pose an increased risk for diabetes and DR at a younger age.

Door to door screening for diabetes and its complications including screening for DR with fundus photography using a handheld nonmydriatic fundus camera was carried out in both urban and rural areas in the SMART India study in 11 states and 1 union territory in 2019–2020.<sup>[30]</sup>

Community outreach programs that are focused primarily to improve access to the underserved have addressed the barriers to eye disorders like cataract in India successfully to a large extent.<sup>[10]</sup> Unlike cataract, DR screening through outreach programs targeting entire population to screen for diabetes and then followed by DR screening may yield a low percentage of DR detection as the prevalence of DR is lower in India.<sup>[9]</sup> It would be beneficial to target high-risk groups and individuals with known diabetes in community DR screening programs to enable DR detection and ensure sustainability of such programs.

*DR screening as a part of community and rural outreach programs*

### **Community outreach DR screening programs**

The major activities in community outreach programs are screening, diagnosing, providing advice to people with early DR regarding glycemic control, life style modification, and regular follow-up (systemic management) and referring those requiring ocular management to secondary and tertiary eye care centers.<sup>[32]</sup> In these programs, individuals with diabetes referred through a network from government and private clinics, general physicians, laboratories, and diabetes screening programs are referred for DR screening. Targeted diabetic eye disease screening programs help in not only identifying DR but also in the detection of other diabetic eye disorders like cataract, glaucoma, retinal vein occlusion, and macular degeneration.

Through a door to door survey, 11,566 people with known diabetes were referred to local DR screening programs organized for individuals with diabetes in urban slums in Delhi.<sup>[32]</sup> Screening and grading of DR was performed by optometrists with a portable handheld nonmydriatic fundus camera. These screening programs were organized in the vision centers, local government dispensaries, or local schools in the slums, within easy reach of residents. Patients who had no DR were advised annual follow-up and those with any DR referred to the nearby base eye hospital. In this program which was conducted with the help of optometrists increased the awareness about DR and DR was detected in 13.5% of the individuals screened.<sup>[32]</sup>

DR screening programs conducted in rural and urban areas in three districts in South India in 2003 screened over 7700 individuals with diabetes and DR was detected in 18% of people in the rural areas and 17% in urban areas. In these programs, individuals with STDR were referred to the base hospital for further management. Alarming, 63% of individuals with diabetes in rural areas and 75% of individuals in urban areas never had DR screening done previously.<sup>[33]</sup>

### **Rural outreach DR screening programs**

To enable DR screening in rural areas where access to trained ophthalmologists is limited, telemedicine is a boon and helps implement rural outreach programs. The World Diabetes Foundation (WDF) has supported many rural outreach projects

to prevent loss of vision due to diabetes and initiate quality services for DR at affordable cost in India.<sup>[34]</sup> Some of the rural-outreach programs are highlighted here.

The Chunampet Rural Diabetes Prevention Project was undertaken with the support of WDF to screen for diabetes and its complications among the rural population (42 villages) in the state of Tamil Nadu using a mobile telemedicine van; retinal imaging was performed using Topcon TRC nonmydriatic camera by trained eye technician in the van.<sup>[35]</sup> In total, 4.9% of the population were diagnosed to have diabetes and 14.6% had prediabetes, and DR was detected in 18.2% of individuals with diabetes.<sup>[35]</sup> To help in periodic follow-up for the rural population, a rural diabetes care center has also been established there.

The Sankara Nethralaya Diabetic Retinopathy Epidemiology and Molecular Genetic Study (SN-DREAMS III) assessed the prevalence of T2D and DR in rural population of South India with retinal photographs taken in a mobile fully equipped van.<sup>[36]</sup> The prevalence of DR in the rural population was found to be 10.3%.<sup>[36]</sup>

A rural health program in Maharashtra assessed the impact of proximity of health care facilities and health education on screening for DR.<sup>[37]</sup> It was found that there was increased acceptance for screening in primary health center, which was closer to home, compared to community health center (24.4% vs. 11.4%;  $P < 0.001$ ) and health education increased the uptake of DR screening.<sup>[37]</sup>

*DR Screening in other health care services*

Screening of DR can also be done in other allied health care facilities like optical shops, pharmacies, etc. Fundus cameras with offline AI for DR in optical shops can be used for opportunistic screening there. A regular DR screening program in collaboration with nephrology clinics can be followed as nephropathy and retinopathy are microvascular complications of diabetes that often coexist.<sup>[26]</sup> People with presbyopia who visit optical shops can be advised to get their blood sugar checked. Laboratories that carry out home blood collection tests during the pandemic can advise people with diabetes to consult a physician for the control of diabetes and to have the retina checked by an eye care provider.

*Risk based DR screening*

Some recent studies have shown that DR screening intervals can be extended and individualized with variable interval based on risk score (age, duration of diabetes, blood sugar control, etc.).<sup>[38]</sup> They have shown that risk-based screening is feasible, safe, and can be cost effective.<sup>[38]</sup>

*Teleophthalmology-Based DR Screening Model*

Telemedicine is a valuable and reliable tool to screen people with diabetes for various complications including DR, providing access to individuals with diabetes living in rural/remote areas to virtual specialist diabetic care and eye care.<sup>[34]</sup> Screening for DR can be done effectively with a teleophthalmology model based on fundus photography and using information technology communication advances for transmission of image data. The teleophthalmic model can bridge gaps in distance, time, and a shortage of skilled manpower in DR screening.<sup>[35]</sup> It can utilize synchronous (real time transfer of images), asynchronous (store and forward),

or hybrid modes for DR screening.<sup>[39]</sup> These models can be integrated into physician offices, diabetes clinics, labs, and primary eye care settings.

### Infrastructure, human resources, and technology for image transfer for teleophthalmology

Affordable, nonmydriatic handheld and desktop fundus cameras with good image resolution are available.<sup>[19]</sup> Hand-held fundus cameras/smartphone-based fundus cameras that are portable, less expensive, and easy to use in remote places are gaining popularity. Physicians, optometrists, and vision technicians can receive training on DR screening and referral guidance.<sup>[24,27]</sup> The capacity building and certifications of these nonophthalmologists in DR and a comprehensive system of electronic medical records are important prerequisites for an ideal Tele-DR screening model.<sup>[27]</sup> Image transfer can be web based or satellite based. Satellite-based models can be advantageous in rural areas with poor connectivity.<sup>[35,40]</sup> Power shortages can be a hindrance in the rural areas where in one can use innovations like solar powered chargers to charge laptops and fundus cameras.<sup>[40]</sup>

### Quality standards: Retinal image protocols for Tele-DR screening

Informed consent should be obtained prior to fundus imaging. A minimum number of five images should be taken for each individual. An external photograph is taken for identification and verification purposes and to avoid duplication of pictures. Anterior segment image can help in detecting referable anterior segment abnormalities and reasons for ungradability like a small pupil/cataract/corneal scars, etc.<sup>[40]</sup> The posterior segment, whenever possible, at least two images per eye (one macula centered and one disc centered) would be important to ensure that DR lesions are not missed.<sup>[16]</sup> All the images should be saved in a folder with the patient's name and unique ID (if possible a mobile number as well) to facilitate recall, retrieval, and tracking.

### Fundus photography technique

The subject should be seated in a comfortable position in a dimly illuminated room to facilitate physiological mydriasis to capture good quality images. It is important that the person is comfortably seated; the rear side of the head should rest against the wall or back rest. This will help to capture quality images with handheld nonmydriatic fundus cameras.<sup>[30]</sup> It is important to monitor the presence and correction of artifacts in a DR screening program as artifacts will affect gradability of images and lead to unnecessary referrals.

### Mydriasis in teleophthalmology

With respect to dilating the pupil for DR screening, there is no specific consensus on the optimal approach. Comparative

trials of mydriatic and nonmydriatic fundus photography have demonstrated that mydriasis significantly reduces the proportion of ungradable photographs and improves both the sensitivity and specificity of DR detection. Mydriasis can improve the image quality by reducing nongradability of digital fundus images from 29.1 to 8.6%.<sup>[41]</sup> For the sake of convenience, for the people who visit the diabetes clinics and for logistical reasons in the absence of a physician, many screening programs employ nonmydriatic retinal imaging, with mydriasis being reserved only when the view is very hazy due to media opacities and fundus photography is unclear. The risk of angle closure glaucoma with pupillary dilatation was found to be insignificant in Asian eyes.<sup>[42]</sup> It was recommended that mydriasis is necessary to improve gradability, reduce inappropriate referrals especially in people above 50 years of age, and Snellen visual acuity worse than 6/12.<sup>[41]</sup> Mydriatic DR screening should be encouraged by eye care facilities unless nonmydriatic ultrawide field cameras (scanning laser ophthalmoscopy like Optos Daytona Plus/Zeiss Clarus, etc.) are used for screening.<sup>[28]</sup>

Table 3 shows the criteria for referral to specialized eye care based on fundus photography in the teleophthalmology model. Rachapelle *et al.*<sup>[43]</sup> reported using the WHO threshold of cost-effectiveness that rural teleophthalmology is cost-effective compared to no screening as long as it is done at an interval longer than 1 year. A study of patient satisfaction comparing remote and in-person screening showed telescreening to be equally satisfactory.<sup>[44]</sup> Telescreening is as good as ophthalmologist led screening for detection of DR.

All ocular complications of diabetes including DR require regular repetitive screening based on the severity of DR and the comorbidities associated with diabetes. Integrated recall systems for screening visits should be part of an ideal screening telemedicine model. Regular audits (both quantitative and qualitative) should form an integral part of this model. AI-enabled DR screening tools can be used to support the nonophthalmic workforce in a tele-DR screening model. AI can alert the eye technician to recognize if the quality of fundus image is good.

### Barriers for DR screening in India

It is challenging to initiate a single national DR systematic screening program in India due to multiple reasons. The resources for nationwide DR screening programs are scarce and the number of people to be screened is large. Cost for screening and treatment for diabetes and DR may be from their own pocket unless it is at government hospital or the cost is covered through health insurance schemes. As public awareness of visual impairment due to diabetes is limited, self-referral for DR screening is not a priority among

**Table 3: Telemedicine criteria for referral to eye care in people with diabetes based on, only retinal color photography**

DR pathology	Non-DR conditions
Diabetic retinopathy (DR) severity worse than moderate nonproliferative DR (NPDR) and above [Above refers to Severe NPDR and proliferative DR (PDR)(early and high risk)]	Drusen at macula/ARMD Other retinal vascular disorders Increased cup disc ratio (glaucoma suspect) Unclear images - poor quality due to nonmydriatic image, poor focus
Moderate and severe diabetic macular edema	Unclear images - due to media opacities - cataract

individuals with diabetes. Friendly interactions between the patient and the ophthalmologist will promote trust and understanding. An integrated approach including awareness and education by counsellors, setting up of patient support groups, and telescreening will be useful in overcoming some of the barriers.<sup>[45]</sup>

It is essential to boost the infrastructural facilities including visual acuity testing, fundus photography/ophthalmoscopy at the primary health care (PHC) level. Trained man-power (optometrists/vision technicians) to screen for DR are also required at the level of PHC to ensure screening at the grass root level. Attention is also required toward improvement of awareness related to DR screening and management. Inclusion of DR into health insurance schemes is required to ensure that sufficient coverage is provided to facilitate cost-effective screening and treatment of DR. The purpose of screening is defeated unless there are recall facilities or established treatment pathways. A national DR registry should be maintained for annual recall for follow-up.<sup>[28]</sup>

## Conclusion

Life-long evaluation for DR by repetitive retinal screening of people with diabetes is a valuable and essential strategy. All the stakeholders perhaps by a public private partnership can play a role in robust screening in a diverse country like India. Cost-effective sustainable models of DR screening should ensure diagnosis and appropriate referral at each hierarchical level right from PHC to secondary health care and to specialized tertiary eye care and diabetes care. Awareness about the need for lifestyle modification and the health seeking behavior among people with diabetes would be important to ensure follow-up and increase the compliance for continued care of diabetes control as well as screening and management of DR. Integrated recall systems are essential. India has to slowly move on from opportunistic screening to systematic screening to prevent blindness due to DR.

Newer technologies, ultrawide field retinal imaging, and handheld sleek and relatively inexpensive fundus cameras, teleophthalmology, and use of AI are improving screening strategies. The ideal screening device for DR for the future would be an automated camera with a high resolution, ultrawide field of view (without the need for dilatation), high sensitivity, and specificity, which is easy to operate by trained technicians, not very expensive and with an integrated AI algorithm for DR detection. It is fervently hoped that such a system would soon become available for large-scale use in India.

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## Conflicts of interest

There are no conflicts of interest.

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