Review Article

Telemedicine in diabetic retinopathy screening in India

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With ever-growing prevalence of diabetes mellitus and its most common microvascular complication diabetic retinopathy (DR) in Indian population, screening for DR early for prevention of development of vision-threatening stages of the disease is becoming increasingly important. Most of the programs in India for DR screening are opportunistic and a universal screening program does not exist. Globally, telemedicine programs have demonstrated accuracy in classification of DR into referable disease, as well as into stages, with accuracies reaching that of human graders, in a cost-effective manner and with sufficient patient satisfaction. In this major review, we have summarized the global experience of telemedicine in DR screening and the way ahead toward planning a national integrated DR screening program based on telemedicine.

Key words: Artificial intelligence, diabetes mellitus, diabetic retinopathy, telemedicine, telescreening, vision threatening

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Diabetes mellitus (DM) prevalence in India has increased from 61.3 million in 2011 to 77 million in 2019; a further 77 million are considered to be prediabetic and is projected to grow to a 101 million by 2030 and 134.2 million by 2045.[1-3] DM prevalence is higher in low- and middle-income countries (LMICs) due to economic transition of most nations, westernization of the lifestyle and improving longevity. Diabetic retinopathy (DR) is an important microvascular complication seen in people with diabetes (PWD) and can cause significant health hazards in working age group.[4] While the earlier stages of DR, mainly the nonproliferative DR (NPDR) stages, may not cause significant visual impairment, diabetic macular edema (DME) and proliferative DR (PDR) can cause significant vision loss and are together named as vision-threatening DR (VTDR). Left untreated, 26% of people with VTDR are likely to be severely vision impaired in 2 years.[5,6] The National Diabetes and Diabetic Retinopathy Survey report 2015–2019 estimated the prevalence of DR as 16.9% in the population ≥50 years, and the prevalence of VTDR as 3.6% in India.[7]

Teleophthalmology and DR

The World Health Organiztion had defined teleophthalmology as the delivery of health care services "using information and communication technologies (ICT) for the exchange of diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers."[8] Teleophthalmology plays a significant role for the screening of many diseases, DR being one of the most important ophthalmic diseases. With strides in the progress in telecommunication, availability of various retinal imaging systems, and integration of offline applications to the smartphones, recent literature has witnessed a surge in studies on telescreening of DR, with impressive sensitivity and specificity for the detection of DR. However, LMICs with regional variations in geopolitics, economy, literature, and accessibility to healthcare face a major challenge in the implementation of a uniform nationwide telescreening model for DR. There are different models of telescreening for DR applicable in different clinical and regional settings. In this review, we summarize the application of teleophthalmology in DR screening across the world and its future importance in LMICs like India, where there is a growing necessity to develop a systematic DR screening program in a cost-effective manner.

Suitability for Screening

According to the WHO, screening should be done for diseases that are an important health problem, have effective treatment which is possible to be delivered early, before the appearance of symptoms, technology for diagnosis is available, screening is feasible and cost effective, and subjects can be followed longitudinally [Table 1].[9] DR fulfils most of these criteria. It has also been shown that screening can reduce the rate of blindness due to DR.[10]

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Conventionally, recommendations for best practices of DR prevention require PWD to visit for ophthalmic follow-ups at least once a year.[11] Annual examinations are recommended for patients under age 30 years starting within 3–5 years after diagnosis of DM. The conventional tools for DR screening include direct ophthalmoscopy, indirect ophthalmoscopy, slit-lamp biomicroscopy, and fundus photography.

Traditionally, screening may be either optometrist driven or ophthalmologist driven; however, both methods may no longer be cost effective in India, with the huge emerging burden of disease, more so in rural India. The amount of time to be invested by each ophthalmologist for annual screening of each PWD is projected to rise exponentially, and hence the concept of in-person examinations are gradually being deemed neither sustainable nor practical and may not be enough to meet the minimum standards for preventing vision loss, particularly in the remote locations where there is a scarcity of trained vitreoretinal surgeons. Even in urban areas having good access to healthcare, annual screenings may be missed due to longer waiting lists and booking periods.[12-16] In this regard, telescreening of the retina for DR may be a disruptive technology.

Challenges in DR Screening

PWD do not visit an ophthalmologist or optometrist till the time they have vision complaints, and by the time they become symptomatic, they would have progressed to the later stages of DR.[17] The high cost of setting up a teleophthalmology program is its biggest deterrent, besides the need of training and maintaining skilled manpower and expensive equipment.[18] Some other major challenges to setting up a telescreening program are attitude to quality of care by ophthalmologists, who are skeptical of a new generation of clinical practices, liability issues, image quality, workflow and management, data security, patient perception, attitudes, etc.[19]

Table 1: WHO screening criteria

Condition should be a significant health problem
There should be an accepted treatment for patients with the disease
Diagnosis and treatment facilities should be available
An early symptomatic or latent stage should be present
There should be a test or examination method
The test should be acceptable to the population
The natural history of the condition should be adequately understood
There should be an agreed policy on patient selection for treatment
Case finding including diagnosis and treatment should be cost effective
Case finding should be a continuous process

Screening Models

DR screening can be broadly divided into two models, opportunistic screening and systematic screening [Table 2].

Opportunistic screening

Opportunistic DR screening is done sporadically. The main drawbacks of opportunistic DR screening are that it may not be able to screen all the population at risk and there is a chance that all screening interventions are not standardized and checked for quality assurance. Praveen PA *et al.*[20] described an affordable opportunistic DR screening model at a tertiary care diabetes clinic by increasing awareness and providing opportunities for DR screening. Muqit *et al.*[21] have established an opportunistic screening in Bangladesh which detects a significant number of patients with VTDR and visual impairment. Most of the DR screening programs established locally in LMICs are opportunistic.

Systematic screening

Systematic DR screening involves active identification of the population at risk in a quality-assured manner and targets the entire population at risk. All the at risk population are given prior information about the screening program. The UK NHS Diabetic Eye Screening Programme is a successful implementation of a systematic DR screening program.[22]

Devices for Telescreening

The typical retinal imaging devices used for the screening of DR include color fundus photography (CFP) and direct and indirect ophthalmoscopy. Due to the noninvasiveness, automation, portability, and high sensitivity and specificity, these devices have made successful miniaturization of the point of care diagnosis of DR. The available devices for screening of DR can be divided into table-top and smartphone-based devices.

Table-top/traditional fundus cameras

Although the modified Airlie house 30° seven-field CFP, encompassing a 75° fundus viewing angle is the gold standard of fundus imaging for the detection of DR, it is practically not possible for screening purposes, because it is laborious, time consuming, and needs a trained photographer.[23] The different table-top fundus cameras[24-27] in current use are summarized in Table 3.

Smartphone-based fundus cameras

Smartphones are universally available today at reasonable costs, and with increased mobile connectivity through internet may prove as very cost-effective alternatives to conventional fundus cameras for screening programs.[33-44] Some of the common smartphone-based devices are tabulated in Table 3.

Table 2: Different settings for DR screening

Opportunistic screening	Systematic screening
• During the regular visit of the diabetic patient to a health care professional • irregular camp-based screening fundus camera-based imaging with teleconsultation in the physician/endocrinologist's clinic sporadically when patient asks the treating doctor for the test for detection of DR • mobile van-based screening occurring at an undefined frequency and covering arbitrary geographic locations	• Regular DR screening camps in the community • vision centers operating full time with telescreening and consultation from the base eye hospital • fundus camera-based imaging with teleconsultation as a routine part of diabetes evaluation in the physician/endocrinologist's clinic

Table 3: Commercially available fundus cameras

Table-top/traditional fundus cameras	Smartphone-based fundus cameras
45-degree single field Sensitivity and specificity of referable DR 78 and 86%, respectively Used in the UK DR screening program Nonmydriatic camera Minimum pixel needed -30 pixel per degree, with 45° width and 40° height **45-degree 2-field** Sensitivity and specificity of referable DR 96% and 89, respectively The FDA approved AI-based DR screening device uses two 45-degree CFP[28] **45-degree 3-field** Sensitivity and specificity of referable DR 92 and 96%, respectively **Ultra-wide field (UWF) CFP** Fundus imaging with 100 degrees or more field[29] Anatomical classification of UWF defined as the retinal image beyond the vortex vein ampullae in all the four quadrants obtained in a single capture[30] • Optos (Optos plc, Scotland) Assesses 200-degree retinal field using confocal scanning laser technology (cSLO) with three wavelengths; blue (488 nm), green (532 nm) , and red (635 nm) Can detect peripheral features of DR in 20% of the eyes without any detectable DR using conventional CFP 33-41% of the Optos UWF may have predominantly peripheral (PPL) distribution of DR lesions[31,32] • Clarus (Carl Zeiss Meditec, US) This uses LED-based cSLO technology and captures a single field of 133°, with montage reaching up to 200 degrees • Heidelberg multicolor scanning laser imaging A special lens can be mounted onto the OCT/SLO camera, providing a 105° pseudocolor image • Centervue Eidon Combines a cSLO technique with a confocal white light imaging to obtain true color CFP covering 60° per image • Mirante (Nidek Inc. Japan) Field of a view of 163° and has options of multimodal imaging The limitations of UWF imaging include high cost, limited portability, and need of good patient cooperation during imaging. Recently several smartphone-based imaging systems have come up, which are easier to use, need much lesser investment and most importantly, are portable and can be used easily by the patients	The OphthalmicDocs Fundus D-eye system Portable Eye Examination Kit (PEEK) device iExaminer (Welch Allyn) DigiSight's mobile ophthalmic camera (Paxos Scope) Ocular cellscope Volk iNview MII RetCam (Make In India Retinal Camera) Smart i-RxCam™ (VisionQuest Biomedical, LLC) Remidio nonmydriatic Fundus on Phone (FOP) device (Remidio Innovative Solutions, Bangalore, India) EyeSelfie (MIT Media Lab)

Two devices which have been designed and manufactured in India are the MII RetCam and the Remidio Fundus on Phone (FOP) device. The MII RetCam is capable of visualizing even the peripheral regions of the retina up to the pars plana.[45] The Remidio FOP device can capture high-resolution images of the retina, uses an annular illumination light source, and can be attached to a smartphone. The FOP smartphone device has been used in a validation study of an offline AI algorithm for a community-based DR screening program in West India, with a sensitivity of 100% for detection of referable DR.[46] The FOP device has lesser ungradable images as compared to routine tabletop fundus cameras.[47] The Remidio FOP NM-10 has been approved by the FDA as a telemedicine-friendly, portable smartphone-based imaging device.

Smartphone ophthalmoscopy can perform satisfactorily in detecting DR as compared to conventional photography, with the highest diagnostic accuracy for PDR (92%), followed by referable DR (91%).[48] Sensitivity of smartphone-based screening is higher for treatment requiring stages of DR.[49] Hence, this may be a better alternative in DR screening programs in LMICs by reducing total costs of implementation and need to be tested more in the community settings. However, these devices require mydriasis for image capture.

Mydriasis and its Role in Imaging

Digital imaging programs using nonmydriatic cameras may have a higher proportion of ungradable images and may lead to higher chances of unnecessary referrals, reducing the cost-effectiveness of the program.[14,50,] Mydriasis seems to reduce this risk.[51] Hence, mydriasis may be considered in subjects with less than 6/12 visual acuity or more than 60 years of age.[52,53]

Some studies have observed that nonmydriatic images may be sufficient for DR and DME detection, and a three-field 45° image may be superior over a single-field image.[25,54] However, mydriasis status alone may not significantly affect the detection sensitivity and patients themselves also prefer nonmydriatic retinal photography.[55]

In this regard, ultrawide field (UWF) imaging technology may help obtain images of better field of view without mydriasis and reduce the proportion of ungradable images. UWF platforms may have higher overall DR and VTDR detection rate and referral rate compared with nonmydriatic multifield photography.[56] However, UWF devices may need a high-resource setting and further validation against American Telemedicine Association (ATA) category standards.

International Guidelines for Telemedicine in Ophthalmology

The reference standard for all telemedicine programs are the ETDRS 30° stereo seven-standard fields, color, 35 mm slides. However, there is no unanimity on the best digital photography protocol which can replace ETDRS photographs in telescreening programs.[57,58] Therefore, the ATA and Ocular Telehealth Special Interest Group have defined different levels of validation for the purpose of standardization of digital photography used in telescreening.[59] The diagnostic accuracy of digital imaging used must be validated and adhere to standards of Digital Imaging and Communication in Medicines (DICOM).[60] Table 4 summarizes the different categories of validation.

Global Experience in Teleophthalmology Programs

Over the past two decades, several studies from various countries have shown successful implementation and running of telescreening programs from the patient, caregiver, and administration's point of view. Although the results of conventional DR screening by optometrists and nonclinical healthcare workers may be marginally lower than trained retina specialists or ophthalmologists, studies using telemedicine with nonmydriatic cameras have shown comparable results with conventional screening.[61-68] Some studies have shown that primary care physicians can also reliably evaluate fundus images after proper training.[69,70]

An example of a very successful national DR telescreening program is that of the UK, which has underlined the importance or monitoring of DR along with the overall glycemic status of patients, so much so that DR has ceased to be a leading cause of blindness in England and Wales.[71] The Teleophthalmological Services Citizen Centered Application or TOSCA provides DR telescreening in Europe and has demonstrated that retinal images can be electronically transmitted easily to distant centers for remote grading.[72]

Davis *et al*.[73] performed a randomized controlled trial comparing the effectiveness of telescreening program with the usual care, using a nonmydriatic fundus camera located in a rural primary care practice. The study observed that by having the ophthalmologist grade retinal images sitting at the university center along with video conferencing with patients, the participation rate of patients in the novel screening program had increased six times, compared to conventional scheduled hospital examination. A summary of programs in various countries in use, according to the levels given by ATA, is given in Table 5.[74]

Most of these programs are primary care office-based and employs trained nurses or nonmedical staff for capturing the fundus images. Grading is done by ophthalmologists, optometrists, or nonophthalmic-trained readers. The programs commonly use two or three nonstereo photos. Scottish DR screening program uses single-field 45-degree macula centered images. A single-field image may be sufficient for detection and referral of DR patients in the community and is relatively less time consuming.[86] All programs, except the UK and Canada use nonmydriatic cameras.

The various retinal findings in the fundus image taken at the time of screening may be confirmed when the patient presents at the main center for examination.[87] Apart from the detection of DR grades, telescreening may also be quite sensitive in the detection of DME with high accuracy.[17]

Teleophthalmology screening may reduce unnecessary hospital visits by patients, and hence a greater number of patients may be effectively screened overall, by reducing the pressures over tertiary care centers. Moreover, the screening frequency of patients may also be smoothly increased, since the screening is being performed at a remote site.[88] A metanalysis of 33 international telescreening studies on DR has observed that the screening programs may be 87% sensitive and 91% specific for the detection of any retinopathy.[19] Moreover, the sensitivity and specificity of detection of mild and moderate NPDR are also significantly high.[89]

The latest country to implement a nationwide DR screening program is Singapore in the form of the Singapore Integrated DR Program (SiDRP) based on telemedicine and centralized reading centers.[90] This program has also shown comparative effectiveness in terms of health outcomes and cost.

A study from South India comparing the effectiveness of an ATA category 1 DR screening program with universal conventional screening found that although the total number of DR cases detected by conventional screening might be more, the proportionate yield of DR is higher with telescreening, taking into account actual hospital attendance.[91] The attendance of actual referred patients was proportionately higher in the telescreening group.

The Aravind Teleophthalmology Network utilizes vision centers having ophthalmic technicians and DR camps to screen

Table 4: Levels of validation as recommended by the ATA-OTSIG

Levels of validation	Application
Category 1	Screen for the presence or absence of greater than minimal DR
Category 2	Screen for patients with and without VTDR
Category 3	To identify ETDRS-defined levels of NPDR (mild, moderate, or severe), PDR (early and high risk), and DME
Category 4	A system that has been shown to match or exceed the ability of ETDRS photographs to identify lesions of DR

Table 5: Established DR screening programs in Western countries

	ATA categories			
	1	2	3	4
DR grading	No or minimal DR	No DR	No DR	No DR
			Mild DR	Mild DR
		Mild or moderate DR	Moderate DR	Moderate DR
	More than minimal DR		Severe NPDR	Severe NPDR
			Early PDR	Early PDR
		Vision threatening DR or DME	High risk DR	High risk DR
			DME	DME
Functions	Screening	Screening and risk stratification	Screening, risk stratification, treatment recommendation	Exceeds ETDRS seven field photos, Can replace ETDRS photos in programs
Programs	Ophdiat (Paris, France)[75]	EyeCheck (Netherlands)[76]	Joslin Vision Netwrok (Massachusetts, USA)[77]	None
	EyePacs (CA, USA)[78,79] Digiscope (Maryland, USA)[63] Aravind Teleophthalmology network (India)[85]	NHS Diabetic Eye Screening program (UK)[52,80-83]	University of Alberta, (Canada)[84]	

patients in remote areas. Photographs are sent to physician graders in central grading centers for grading and patients are referred to higher centers if needed.[91] The responsibility of image acquisition is very important for all programs and depends on quality assurance protocols, which have been put in place to improve and maintain the quality of images taken, and reduce the rate of ungradable images.[92]

Cost Effectiveness of Telescreening Programs

The parameters on which a successful teleophthalmology program can run are diagnostic accuracy and cost effectiveness.[18] Although 50–90% of population may need some form of DR screening, only about 10% will end up requiring management for vision loss.[93] Hence, in-person examinations need to be reduced with the help of teleophthalmology programs using a universal screening model. Although there may be an initial requirement of substantial capital investment for implementation, the overall final cost benefit is larger than conventional screening programs.[89] The cost effectiveness of DR screening programs has been evaluated internationally, especially for detection of VTDR.[94-98]

Telescreening setting

Mobile community-based screening services help increase recruitment and community participation.[99] Moreover, the effectiveness of the program increases when DR screening is combined with screening for other diseases the population may be at risk of.[100] Preventive programs for PWD produce significant savings; hence, they are highly cost effective for society in general, especially DR being the most cost effective and cost saving.[101-103]

The costs of grading in a reading center are lower, and higher specificity of the DR grades means lesser unnecessary referrals to the base hospital. The SiDRP reported cost savings of $173 per patient compared to the preexisting family physician driven model.[92] Although from a public health view, ophthalmoscopy appears less costly due to requirement of lower capital investment, from a global perspective, teleophthalmology is more efficient, since it reduces travel and time cost and loss of income of patients.[104] Finally, telescreening may provide better cost benefits in the LMIC countries.[105,106]

Factors driving costs

Populations screened at a younger age, having higher HBA1c or having higher transportation costs have the most benefit from telescreening.[107,108] The cost effectiveness also depends on the disease burden and population size, especially at a higher workload.[108]

Another important factor guiding the cost is the screening interval, which may be individualized based on the risk level of patients.[109-111] PWD with no DR have a relatively low risk of developing VTDR over 2 years, irrespective of one-field or two-field fundus screenings.[112,113] By stratifying patients into low-risk and high-risk groups and subsequent adaptation of individualized screening intervals, cost reduction can be achieved.[114,115]

A rural teleophthalmology screening program in India found that the program was cost-effective ($1320 per QALY (Quality adjusted life years)) as compared to no screening at all.[109] The study also evaluated that a biannual screening may be more cost effective than annual screening (>$3183 per QALY).

Artificial Intelligence and Role in Telescreening

Human grading being a subjective task is prone to mislabeling due to several factors like exhaustion, misidentification, and fatigue and may lead to uncertainty of the results. Moreover, there is no gold standard for the perfect grading. Automated analysis can bring objectivity and repeatability to DR screening and grading and may help reduce the burden of human grading. Deep learning systems (DLS) have already shown good results in multiple medical diseases. Automated algorithms for DR detection have shown good accuracy for the presence of moderate and severe DR as well as DME.

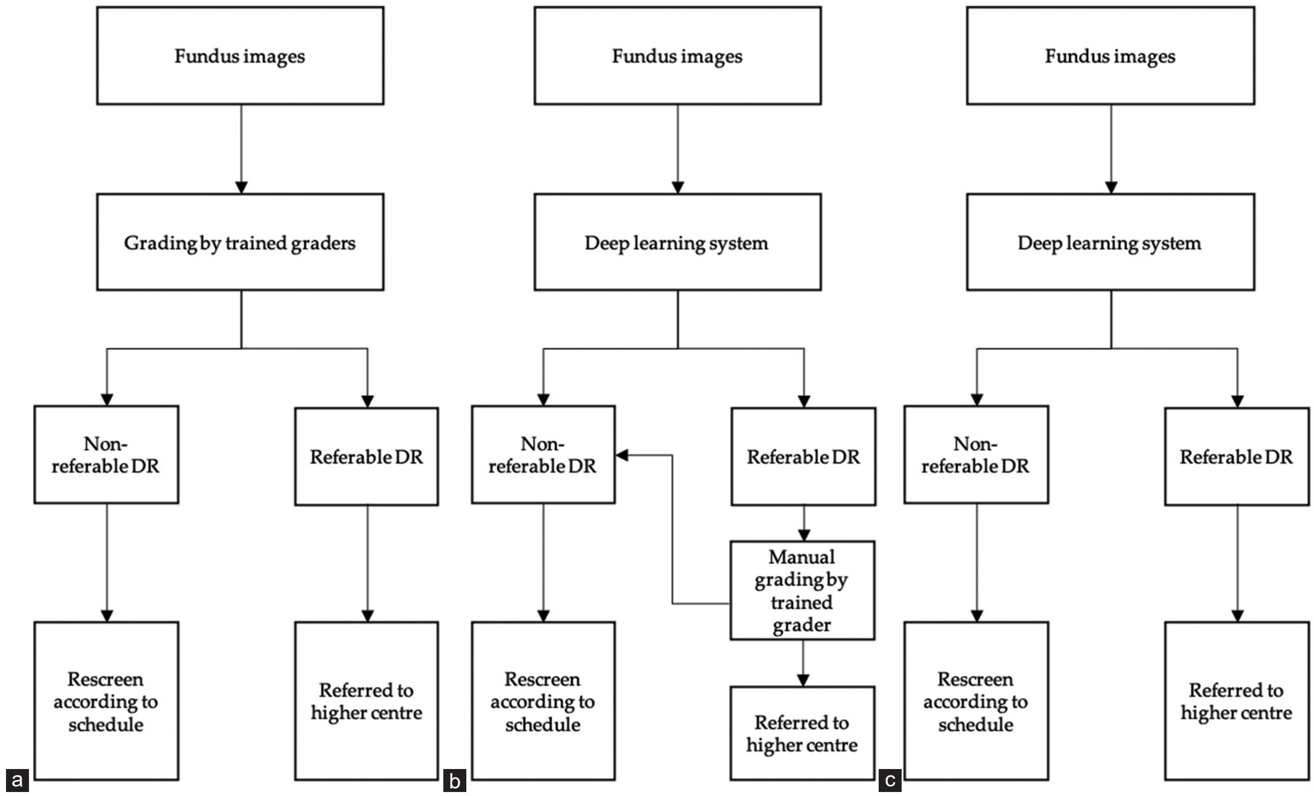

Figure 1: (a) Conventional teleophthalmology screening model. (b) Semiautomated AI based screening model. (c) Fully automated AI-based screening model

Multiple Indian eye centers are involved in development and validation of artificial intelligence-based algorithms in DR.[116-118] Recently, a Singapore-based DLS has been noted to have comparable diagnostic accuracy to human graders.[119] A semiautomated DLS model involving a secondary human assessment may be the most cost-effective model [Fig.1].[120] A fully automated system may suffer from false positive data, leading to unnecessary specialist visits and increasing costs.

The USFDA has recently authorized IDx-DR, an autonomous AI system, for use in adults aged 22 years or older, for detection of DR stages more than mild DR and DME, based on multilayer convolutional neural networks.[28] It has a sensitivity of 87.2%, specificity of 90.7%, and an imageability rate of 96.1%, and it has performed superiorly to all high-quality predetermined standards.

Model Teleophthalmology Practice Guidelines

The design, planning, programming, implementation, and sustenance of telescreening programs need cooperation among public and private organizations and national and international agencies.[121] Clearly defined mission, vision, and guiding principles are required for effective running of the program. Generally, all programs should target to improve the access and availability of eye health via telescreening, reduce costs of healthcare, and enhance the efficacy of management of DR.

The programs must be developed and deployed in a safe manner and should be closely monitored so that they meet the overall standards of care. Patients need to be explained that the screening is not a replacement of existing hospital/center-based facilities. All programs must undergo an internal examination for ATA category validation determination to ascertain performance standards and program goals. The program's validation category may impact the operational features and business model of the program.

Personnel specifications

- Human resource allocation for specifically defined function in the telescreening program is required for efficient running.
- Image acquisition personnel
- Medical supervisor (ophthalmologist or optometrist)
- Image grading personnel
- Information technology personnel

Technical guidelines

- Equipment under the telescreening program need to conform to the national drugs and devices regulating agency. These include:
- Image capturing devices (cameras, computers)
- Image transmission and storage facilities
- Image enhancement technologies
- Data management, storage (PACS, DICOM) and data security

Administrative guidelines

- Legal requirements for accreditation, insurance, patient consent
- Quality control and maintenance of professional standards
- Customer support

Operational standards guidelines

- Data registry
- Training of manpower
- Management of referral of patients
- Non-attendance rates
- Re-call screened patients

Initiatives of Teleophthalmological Society of India

The Teleophthalmology Society of India (TOSI) was established with an aim to promote research and training toward development of teleophthalmology practices, advocacy, organization of symposia, seminars, and courses for training of personnel. In the coming days, TOSI is to play an instrumental role in the process of developing and implementation of teleophthalmology DR screening by developing guidelines, training programs, and promoting telescreening among all the stakeholders, especially ophthalmologists, general physicians, endocrinologists, image graders, technicians, etc.

Telescreening Management and Diabetic Retinopathy Registry

To ensure a proper running of a DR telescreening program in India, the health management information systems in the country need to ensure the incorporation of infrastructure and equipment. Insurance providers like the Ayushman Bharat can provide for the financing and reimbursement of costs. All patients screened in the program need to be registered with an identification number with all their clinical data stored and backed up. The retinal images are to be transmitted digitally in a picture archiving and communication systems format and stored and transferred by DICOM. These registries may be set up as public–private partnerships.[122]

Patient Satisfaction Related to Telescreening of DR

Telescreening of DR is gaining more popularity among patients. In a study done in Kenya, PWD found that the telescreening method was more convenient than the conventional clinical detection of DR.[123] In a prospective study of telescreening of DR using a nonmydriatic camera, 98.6% of the patients found the telescreening method acceptable, 95.1% wanted their next DR screening to be through teleconsultation and 91.2% stated it would increase their compliance to annual screening.[16]

Conclusion

With an ever-increasing incidence of diabetes in LMICs like India, the economic cost of diabetes related complications especially DR will be very high. The national DR screening teleophthalmology program in the United Kingdom is a very good example that the developing countries can follow and integrate DR telescreening in the already established national programs like NPCB, NPCDCS, etc. All the abovementioned opportunities should be used to implement DR screening in National noncommunicable diseases programs. A multidisciplinary collaborative approach must be undertaken in order to improve retinopathy detection in the early stage of the disease. A primary care physician/an endocrinologist or PHCs can be the first point of contact for the PWD, and this strategy will ensure the probability of having a retinal screening. Therefore, if primary care or multispecialty clinics are equipped with fundus cameras, especially in areas without access to eye care specialists, the coverage of screening would increase. With the advent of AI, this telescreening process can very well be accelerated as the dependency on human resources for grading will be greatly reduced. Moreover, AI will bring in much better consistency and will be available round the clock. With improvements in AI algorithms, this process will improve not only screening for DR but also early identification of many other diseases affecting the retina. Automated screening systems are not limited to DR and may be applicable for other conditions, such as age-related macular degeneration and glaucoma, where earlier detection would likely improve clinical outcome. Today many such algorithms are available. Rigorous validation testing of all such algorithms should be done to determine suitability for clinical implementation.

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Conflicts of interest

There are no conflicts of interest.

References

1. International Diabetes Federation. IDF Diabetes Atlas. 9th ed. Brussels: Belgium; International Diabetes Federation, 2019. Available from: https://www.diabetesatlas.org/en/resources/. [Last accessed on 2021 May 17].
2. Anjana RM, Deepa M, Pradeepa R, Mahanta J, Narain K, Das HK, *et al*. Prevalence of diabetes and prediabetes in 15 states of India: Results from the ICMR-INDIAB population-based cross-sectional study. Lancet Diabetes Endocrinol 2017;5:585-96.
3. Whiting DR, Guariguata L, Weil C, Shaw J. IDF diabetes atlas: Global estimates of the prevalence of diabetes for 2011 and 2030. Diabetes Res Clin Pract 2011;94:311-21.
4. American Diabetes Association. Standards of medical care in diabetes--2008. Diabetes Care 2008;31:S12-54.
5. Photocoagulation treatment of proliferative diabetic retinopathy. Clinical application of diabetic retinopathy study (DRS) findings, DRS report number 8. The Diabetic Retinopathy Study Research Group. Ophthalmology 1981;88:583-600.
6. Early photocoagulation for diabetic retinopathy. ETDRS report number 9. Early Treatment Diabetic Retinopathy Study Research Group. Ophthalmology 1991;98:766-85.
7. National Programme for Control of Blindness. National blindness and visual impairment survey India 2015-2019 - A summary report. New Delhi: Ministry of Health and Family Welfare, Government of India. Available from: https://npcbvi.gov.in/writeReadData/mainlinkFile/File341.pdf. [Last accessed on 2021 May 17].
8. World Health Organization. WHO Group Consultation on Health Telematics (1997: Geneva, Switzerland). A health telematics policy in support of WHO's Health-for-all strategy for global health development: Report of the WHO Group Consultation on Health Telematics, 11-16 December, Geneva, 1997. 1998. Available from: https://apps.who.int/iris/handle/10665/63857.
9. Wilson JMG, Jungner G, Organization WH. Principles and Practice of Screening for Disease. Geneva: World Health Organization; 1968. Available from: https://apps.who.int/iris/handle/10665/37650. [Last accessed on 2021 May 17].
10. Rohan TE, Frost CD, Wald NJ. Prevention of blindness by screening for diabetic retinopathy: A quantitative assessment. BMJ

1989;299:1198-201.
11. Mukamel DB, Bresnick GH, Wang Q, Dickey CF. Barriers to compliance with screening guidelines for diabetic retinopathy. Ophthalmic Epidemiol 1999;661-72.
12. Gower EW, Silverman E, Cassard SD, Williams SK, Baldonado K, Friedman DS. Barriers to attending an eye examination after vision screening referral within a vulnerable population. J Health Care Poor Underserved 2013;24:1042-52.
13. Chin EK, Ventura BV, See K-Y, Seibles J, Park SS. Nonmydriatic fundus photography for teleophthalmology diabetic retinopathy screening in rural and urban clinics. Telemed J E Health 2014;20:102-8.
14. Boucher MC, Desroches G, Garcia-Salinas R, Kherani A, Maberley D, Olivier S, *et al*. Teleophthalmology screening for diabetic retinopathy through mobile imaging units within Canada. Can J Ophthalmol 2008;43:658-68.
15. Adriono G, Wang D, Octavianus C, Congdon N. Use of eye care services among diabetic patients in urban Indonesia. Arch Ophthalmol 2011;129:930-5.
16. Boucher MC, Nguyen QT, Angioi K. Mass community screening for diabetic retinopathy using a nonmydriatic camera with telemedicine. Can J Ophthalmol 2005;40:734-42.
17. Liesenfeld B, Kohner E, Piehlmeier W, Kluthe S, Aldington S, Porta M, *et al*. A telemedical approach to the screening of diabetic retinopathy: Digital fundus photography. Diabetes Care 2000;23:345-8.
18. Salongcay RP, Silva PS. The role of teleophthalmology in the management of diabetic retinopathy. Asia Pac J Ophthalmol (Phila) 2018;7:17-21.
19. Ullah W, Pathan SK, Panchal A, Anandan S, Saleem K, Sattar Y, *et al*. Cost-effectiveness and diagnostic accuracy of telemedicine in macular disease and diabetic retinopathy: A systematic review and meta-analysis. Medicine (Baltimore) 2020;99:e20306.
20. Praveen PA, Venkatesh P, Tandon N. Screening model for diabetic retinopathy among patients with type 1 diabetes attending a tertiary care setting in India. Indian J Ophthalmol 2020;68:S96-9.
21. Muqit MMK, Kourgialis N, Jackson-deGraffenried M, Talukder Z, Khetran ER, Rahman A, *et al*. Trends in diabetic retinopathy, visual acuity, and treatment outcomes for patients living with diabetes in a fundus photograph-based diabetic retinopathy screening program in Bangladesh. JAMA Netw Open 2019;2:e1916285.
22. Papavasileiou E, Dereklis D, Oikonomidis P, Grixti A, Vineeth Kumar B, Prasad S. An effective programme to systematic diabetic retinopathy screening in order to reduce diabetic retinopathy blindness. Hell J Nucl Med 2014;17:30-4.
23. Early Treatment Diabetic Retinopathy Study Research Group. Grading diabetic retinopathy from stereoscopic color fundus photographs--an extension of the modified Airlie House classification. ETDRS report number 10. Early Treatment Diabetic Retinopathy Study Research Group. Ophthalmology 1991;98:786-806.
24. Lin DY, Blumenkranz MS, Brothers RJ, Grosvenor DM. The sensitivity and specificity of single-field nonmydriatic monochromatic digital fundus photography with remote image interpretation for diabetic retinopathy screening: A comparison with ophthalmoscopy and standardized mydriatic color photography. Am J Ophthalmol 2002;134:204-13.
25. Vujosevic S, Benetti E, Massignan F, Pilotto E, Varano M, Cavarzeran F, *et al*. Screening for diabetic retinopathy: 1 and 3 nonmydriatic 45-degree digital fundus photographs vs 7 standard early treatment diabetic retinopathy study fields. Am J Ophthalmol 2009;148:111-8.
26. Aptel F, Denis P, Rouberol F, Thivolet C. Screening of diabetic retinopathy: Effect of field number and mydriasis on sensitivity and specificity of digital fundus photography. Diabetes Metab 2008;34:290-3.
27. Piyasena MMPN, Murthy GVS, Yip JLY, Gilbert C, Peto T, Gordon I, *et al*. Systematic review and meta-analysis of diagnostic accuracy of detection of any level of diabetic retinopathy using digital retinal imaging. Syst Rev 2018;7:182.
28. Abràmoff MD, Lavin PT, Birch M, Shah N, Folk JC. Pivotal trial of an autonomous AI-based diagnostic system for detection of diabetic retinopathy in primary care offices. NPJ Digit Med 2018;1:39.
29. Fenner BJ, Wong RLM, Lam W-C, Tan GSW, Cheung GCM. Advances in retinal imaging and applications in diabetic retinopathy screening: A review. Ophthalmol Ther 2018;7:333-46.
30. Choudhry N, Duker JS, Freund KB, Kiss S, Querques G, Rosen R, *et al*. Classification and guidelines for widefield imaging: Recommendations from the International Widefield Imaging Study Group. Ophthalmol Retina 2019;3:843-9.
31. Verma A, Alagorie AR, Ramasamy K, van Hemert J, Yadav NK, Pappuru RR, *et al*. Distribution of peripheral lesions identified by mydriatic ultra-wide field fundus imaging in diabetic retinopathy. Graefes Arch Clin Exp Ophthalmol 2020;258:725-33.
32. Aiello LP, Odia I, Glassman AR, Melia M, Jampol LM, Bressler NM, *et al*. Comparison of early treatment diabetic retinopathy study standard 7-field imaging with ultrawide-field imaging for determining severity of diabetic retinopathy. JAMA Ophthalmol 2019;137:65-73.
33. Haddock LJ, Kim DY, Mukai S. Simple, inexpensive technique for high-quality smartphone fundus photography in human and animal eyes. J Ophthalmol 2013;2013:518479. doi: 10.1155/2013/518479.
34. Maamari RN, Keenan JD, Fletcher DA, Margolis TP. A mobile phone-based retinal camera for portable wide field imaging. Br J Ophthalmol 2014;98:438-41.
35. Navitsky C. The portable eye examination kit. Retina Today 2013. Available from: https://retinatoday.com/articles/2013-nov-dec/the-portable-eye-examination-kit. [Last accessed on 2021 May 17].
36. Paxos Scope. Digisight Technologies Inc. Available from: https://www.digisight.net/digisight/paxos-scope.php. Link is not available. [Last accessed on 2021 May 07].
37. Volk iNview. Volk Optical Inc. Available from: https://www.deviceoptical.com/pd-volk-inview-fundus-camera.cfm. [Last accessed on 2021 May 17].
38. MII Ret Cam Inc. Available from: http://www.miiretcam.com/. [Last accessed on 2021 May 17].
39. i-RxCamTM. VisionQuest Biomedical LLC. Available from: https://www.visionquest-bio.com/product/irx-therm/. [Last accessed on 2021 May 17].
40. Non-mydriatic Fundus on Phone (FOP). Remidio Innovative Solutions Pvt. Ltd. Available from: https://www.remidio.us/fop.php. [Last accessed on 2021 May 17].
41. Swedish T, Roesch K, Lee IH, Rastogi K, Bernstein S, Raskar R. EyeSelfie: Self directed eye alignment using reciprocal eye box imaging. ACM Trans Graphics 2015;34:58. Available from: https://dspace.mit.edu/handle/1721.1/103752. [Last accessed on 2021 May 17].
42. Myung D, Jais A, He L, Blumenkranz MS, Chang RT. 3D printed smartphone indirect lens adapter for rapid, high quality retinal imaging. J Mob Technol Med 2014;3:9-15.
43. oDocs Eye Care. Research & Publications. Available from: https://www.odocs-tech.com/research. [Last accessed on 2021 May 17].
44. D-EYE portable retinal imaging system. Available from: https://www.d-eyecare.com/en_IN/product. [Last accessed on 2021 May 17].
45. Sharma A, Subramaniam SD, Ramachandran KI, Lakshmikanthan C, Krishna S, Sundaramoorthy SK. Smartphone-based fundus camera device (MII Ret Cam) and technique with ability to image peripheral retina. Eur J Ophthalmol 2016;26:142-4.
46. Natarajan S, Jain A, Krishnan R, Rogye A, Sivaprasad S. Diagnostic accuracy of community-based diabetic retinopathy screening with an offline artificial intelligence system on a smartphone. JAMA Ophthalmol 2019;137:1182-8.
47. Sengupta S, Sindal MD, Baskaran P, Pan U, Venkatesh R. Sensitivity and specificity of smartphone-based retinal imaging for diabetic retinopathy: A comparative study. Ophthalmol Retina 2019;3:146-53.
48. Tan CH, Kyaw BM, Smith H, Tan CS, Tudor Car L. Use of

smartphones to detect diabetic retinopathy: Scoping review and meta-analysis of diagnostic test accuracy studies. J Med Internet Res 2020;22:e16658.
49. Bilong Y, Katte J-C, Koki G, Kagmeni G, Obama OPN, Fofe HRN, *et al*. Validation of smartphone-based retinal photography for diabetic retinopathy screening. Ophthalmic Surg Lasers Imaging Retina 2019;50:S18-22.
50. Scanlon PH, Malhotra R, Thomas G, Foy C, Kirkpatrick JN, Lewis-Barned N, *et al*. The effectiveness of screening for diabetic retinopathy by digital imaging photography and technician ophthalmoscopy. Diabet Med 2003;20:467-74.
51. Murgatroyd H, Ellingford A, Cox A, Binnie M, Ellis JD, MacEwen CJ, *et al*. Effect of mydriasis and different field strategies on digital image screening of diabetic eye disease. Br J Ophthalmol 2004;88:920-4.
52. Raman R, Rani PK, Mahajan S, Paul P, Gnanamoorthy P, Krishna MS, *et al*. The tele-screening model for diabetic retinopathy: evaluating the influence of mydriasis on the gradability of a single-field 45 degrees digital fundus image. Telemed J E Health 2007;13:597-602.
53. Murgatroyd H, Cox A, Ellingford A, Ellis JD, Macewen CJ, Leese GP. Can we predict which patients are at risk of having an ungradeable digital image for screening for diabetic retinopathy? Eye (Lond) 2008;22:344-8.
54. Raman R, Rani PK, Sharma T. The sensitivity and specificity of nonmydriatic digital stereoscopic retinal imaging in detecting diabetic retinopathy: Response to Ahmed *et al*. Diabetes Care 2007;30:e47.
55. Bragge P, Gruen RL, Chau M, Forbes A, Taylor HR. Screening for presence or absence of diabetic retinopathy: A meta-analysis. Arch Ophthalmol 2011;129:435-44.
56. Silva PS, Horton MB, Clary D, Lewis DG, Sun JK, Cavallerano JD, *et al*. Identification of diabetic retinopathy and ungradable image rate with ultrawide field imaging in a national teleophthalmology program. Ophthalmology 2016;123:1360-7.
57. Wilkinson CP, Ferris FL, Klein RE, Lee PP, Agardh CD, Davis M, *et al*. Proposed international clinical diabetic retinopathy and diabetic macular edema disease severity scales. Ophthalmology 2003;110:1677-82.
58. American Telemedicine Association. Core operational guidelines for telehealth services involving provider-patient interactions. American Telemedicine Association; 2014. Available from: https://www.americantelemed.org/resources/core-operational-guidelines-for-telehealth-services-involving-provider-patient-interactions/. [Last accessed on 2021 May 17].
59. Cavallerano J, Lawrence MG, Zimmer-Galler I, Bauman W, Bursell S, Gardner WK, *et al*. Telehealth practice recommendations for diabetic retinopathy. Telemed J E Health 2004;10:469-82.
60. Li HK, Horton M, Bursell S-E, Cavallerano J, Zimmer-Galler I, Tennant M, *et al*. Telehealth practice recommendations for diabetic retinopathy, second edition. Telemed J E Health 2011;17:814-37.
61. Seoud L, Hurtut T, Chelbi J, Cheriet F, Langlois JMP. Red lesion detection using dynamic shape features for diabetic retinopathy screening. IEEE Trans Med Imaging 2016;35:1116-26.
62. Hammond CJ, Shackleton J, Flanagan DW, Herrtage J, Wade J. Comparison between an ophthalmic optician and an ophthalmologist in screening for diabetic retinopathy. Eye (Lond) 1996;10:107-12.
63. Kleinstein RN, Roseman JM, Herman WH, Holcombe J, Louv WC. Detection of diabetic retinopathy by optometrists. J Am Optom Assoc 1987;58:879-82.
64. Sussman EJ, Tsiaras WG, Soper KA. Diagnosis of diabetic eye disease. JAMA 1982;247:3231-4.
65. de Sonnaville JJ, van der Feltz van der Sloot D, Ernst L, Wijkel D, Heine RJ. Retinopathy screening in type 2 diabetes: Reliability of wide angle fundus photography. Diabet Med 1996;13:482-6.
66. Williams R, Nussey S, Humphry R, Thompson G. Assessment of non-mydriatic fundus photography in detection of diabetic retinopathy. Br Med J (Clin Res Ed) 1986;293:1140-2.
67. Joannou J, Kalk WJ, Mahomed I, Ntsepo S, Berzin M, Joffe BI, *et al*. Screening for diabetic retinopathy in South Africa with 60 degrees retinal colour photography. J Intern Med 1996;23:943-7.
68. Javitt JC, Aiello LP. Cost-effectiveness of detecting and treating diabetic retinopathy. Ann Intern Med 1996;124:164-9.
69. Rodríguez Villa S, Alonso Álvarez C, de Dios Del Valle R, Salazar Méndez R, Cuesta García M, Ruiz García MJ, *et al*. Five-year experience of tele-ophthalmology for diabetic retinopathy screening in a rural population. Arch Soc Esp Oftalmol 2016;91:426-30.
70. Andonegui J, Serrano L, Eguzkiza A, Berástegui L, Jiménez-Lasanta L, Aliseda D, *et al*. Diabetic retinopathy screening using tele-ophthalmology in a primary care setting. J Telemed Telecare 2010;16:429-32.
71. Liew G, Michaelides M, Bunce C. A comparison of the causes of blindness certifications in England and Wales in working age adults (16-64 years), 1999-2000 with 2009-2010. BMJ Open 2014;4:e004015.
72. Luzio S, Hatcher S, Zahlmann G, Mazik L, Morgan M, Liesenfeld B, *et al*. Feasibility of using the TOSCA telescreening procedures for diabetic retinopathy. Diabet Med 2004;21:1121-8.
73. Davis RM, Fowler S, Bellis K, Pockl J, Al Pakalnis V, Woldorf A. Telemedicine improves eye examination rates in individuals with diabetes: A model for eye-care delivery in underserved communities. Diabetes Care 2003;26:2476.
74. Tozer K, Woodward MA, Newman-Casey PA. Telemedicine and diabetic retinopathy: Review of published screening programs. J Endocrinol Diabetes 2015;2. doi: 10.15226/2374-6890/2/4/00131.
75. Massin P, Erginay A, Ben Mehidi A, Vicaut E, Quentel G, Victor Z, *et al*. Evaluation of a new non-mydriatic digital camera for detection of diabetic retinopathy. Diabet Med 2003;20:635-41.
76. Abramoff MD, Suttorp-Schulten MSA. Web-based screening for diabetic retinopathy in a primary care population: The EyeCheck project. Telemed J E Health 2005;11:668-74.
77. Ahmed J, Ward TP, Bursell S-E, Aiello LM, Cavallerano JD, Vigersky RA. The sensitivity and specificity of nonmydriatic digital stereoscopic retinal imaging in detecting diabetic retinopathy. Diabetes Care 2006;29:2205-9.
78. Litvin TV, Ozawa GY, Bresnick GH, Cuadros JA, Muller MS, Elsner AE, *et al*. Utility of hard exudates for the screening of macular edema. Optom Vis Sci 2014;91:370-5.
79. Zimmer-Galler IE. Diabetic retinopathy assessment in the primary care environment: Lessons learned from 100,000 patient encounters. **In: Yogesan K, Goldschmidt L, Cuadros J, editors**. Digital Teleretinal Screening: Teleophthalmology in Practice. Berlin, Heidelberg: Springer; 2012. p. 117-26.
80. Taylor DJ, Fisher J, Jacob J, Tooke JE. The use of digital cameras in a mobile retinal screening environment. Diabet Med 1999;16:680-6.
81. Rudnisky CJ, Tennant MTS, Weis E, Ting A, Hinz BJ, Greve MDJ. Web-based grading of compressed stereoscopic digital photography versus standard slide film photography for the diagnosis of diabetic retinopathy. Ophthalmology 2007;114:1748-54.
82. Sharp PF, Olson J, Strachan F, Hipwell J, Ludbrook A, O'Donnell M, *et al*. The value of digital imaging in diabetic retinopathy. Health Technol Assess 2003;7:1-119.
83. Olson JA, Strachan FM, Hipwell JH, Goatman KA, McHardy KC, Forrester JV, *et al*. A comparative evaluation of digital imaging, retinal photography and optometrist examination in screening for diabetic retinopathy. Diabet Med 2003;20:528-34.
84. Rudnisky CJ, Hinz BJ, Tennant MTS, de Leon AR, Greve MDJ. High-resolution stereoscopic digital fundus photography versus contact lens biomicroscopy for the detection of clinically significant macular edema. Ophthalmology 2002;109:267-74.
85. Bai VT, Murali V, Kim R, Srivatsa SK. Teleophthalmology-based rural eye care in India. Telemed J E Health 2007;13:313-21.
86. Williams GA, Scott IU, Haller JA, Maguire AM, Marcus D, McDonald HR. Single-field fundus photography for diabetic retinopathy screening: A report by the American Academy of Ophthalmology. Ophthalmology 2004;111:1055-62.
87. Tennant MT, Greve MD, Rudnisky CJ, Hillson TR, Hinz BJ. Identification of diabetic retinopathy by stereoscopic digital imaging via teleophthalmology: A comparison to slide film. Can J Ophthalmol 2001;36:187-96.

88. Mansberger SL, Sheppler C, Barker G, Gardiner SK, Demirel S, Wooten K, *et al*. Long-term comparative effectiveness of telemedicine in providing diabetic retinopathy screening examinations: A randomized clinical trial. JAMA Ophthalmol 2015;133:518-25.
89. Zimmer-Galler IE, Zeimer R. Telemedicine in diabetic retinopathy screening. Int Ophthalmol Clin 2009;49:75-86.
90. Nguyen HV, Tan GSW, Tapp RJ, Mital S, Ting DSW, Wong HT, *et al*. Cost-effectiveness of a national telemedicine diabetic retinopathy screening program in Singapore. Ophthalmology 2016;123:2571-80.
91. Joseph S, Kim R, Ravindran RD, Fletcher AE, Ravilla TD. Effectiveness of teleretinal imaging-based hospital referral compared with universal referral in identifying diabetic retinopathy: A cluster randomized clinical trial. JAMA Ophthalmol 2019;137:786-92.
92. Schulze-Döbold C, Erginay A, Robert N, Chabouis A, Massin P. Ophdiat(®): Five-year experience of a telemedical screening programme for diabetic retinopathy in Paris and the surrounding area. Diabetes Metab 2012;38:450-7.
93. Fong DS, Aiello LP, Ferris FL, Klein R. Diabetic retinopathy. Diabetes Care 2004;27:2540-53.
94. Lairson DR, Pugh JA, Kapadia AS, Lorimor RJ, Jacobson J, Velez R. Cost-effectiveness of alternative methods for diabetic retinopathy screening. Diabetes Care 1992;15:1369-77.
95. Maberley D, Walker H, Koushik A, Cruess A. Screening for diabetic retinopathy in James Bay, Ontario: A cost-effectiveness analysis. CMAJ 2003;168:160-4.
96. Whited JD, Datta SK, Aiello LM, Aiello LP, Cavallerano JD, Conlin PR, *et al*. A modeled economic analysis of a digital tele-ophthalmology system as used by three federal health care agencies for detecting proliferative diabetic retinopathy. Telemed J E Health 2005;11:641-51.
97. Scotland GS, McNamee P, Philip S, Fleming AD, Goatman KA, Prescott GJ, *et al*. Cost-effectiveness of implementing automated grading within the national screening programme for diabetic retinopathy in Scotland. Br J Ophthalmol 2007;91:1518-23.
98. Tufail A, Rudisill C, Egan C, Kapetanakis VV, Salas-Vega S, Owen CG, *et al*. Automated diabetic retinopathy image assessment software: Diagnostic accuracy and cost-effectiveness compared with human graders. Ophthalmology 2017;124:343-51.
99. Lee SJ, McCarty CA, Sicari C, Livingston PM, Harper CA, Taylor HR, *et al*. Recruitment methods for community-based screening for diabetic retinopathy. Ophthalmic Epidemiol 2000;7:209-18.
100. Park D-W, Mansberger SL. Eye disease in patients with diabetes screened with telemedicine. Telemed J E Health 2017;23:113-8.
101. Javitt JC. Cost savings associated with detection and treatment of diabetic eye disease. Pharmacoeconomics 1995;8:33-9.
102. Silva P, Cavallerano J, Paz-Pacheco E, Aiello LP. Diabetic retinopathy in Southeast Asia: A call for ocular telehealth programs. J ASEAN Fed Endocr Soc 2014;27:176.
103. Wilson C, Horton M, Cavallerano J, Aiello LM. Addition of primary care-based retinal imaging technology to an existing eye care professional referral program increased the rate of surveillance and treatment of diabetic retinopathy. Diabetes Care 2005;28:318-22.
104. Gomez-Ulla F, Alonso F, Aibar B, Gonzalez F. A comparative cost analysis of digital fundus imaging and direct fundus examination for assessment of diabetic retinopathy. Telemed J E Health 2008;14:912-8.
105. Chua J, Lim CXY, Wong TY, Sabanayagam C. Diabetic retinopathy in the Asia-Pacific. Asia Pac J Ophthalmol (Phila) 2018;7:3-16.
106. Sasso FC, Pafundi PC, Gelso A, Bono V, Costagliola C, Marfella R, *et al*. Telemedicine for screening diabetic retinopathy: The NO BLIND Italian multicenter study. Diabetes Metab Res Rev 2019;35:e3113.
107. Aoki N, Dunn K, Fukui T, Beck JR, Schull WJ, Li HK. Cost-effectiveness analysis of telemedicine to evaluate diabetic retinopathy in a prison population. Diabetes Care 2004;27:1095-101.
108. Kirkizlar E, Serban N, Sisson JA, Swann JL, Barnes CS, Williams MD. Evaluation of telemedicine for screening of diabetic retinopathy in the Veterans Health Administration. Ophthalmology 2013;120:2604-10.
109. Rachapelle S, Legood R, Alavi Y, Lindfield R, Sharma T, Kuper H, *et al*. The cost-utility of telemedicine to screen for diabetic retinopathy in India. Ophthalmology 2013;120:566-73.
110. Rein DB, Wittenborn JS, Zhang X, Allaire BA, Song MS, Klein R, *et al*. The cost-effectiveness of three screening alternatives for people with diabetes with no or early diabetic retinopathy. Health Serv Res 2011;46:1534-61.
111. Vijan S, Hofer TP, Hayward RA. Cost-utility analysis of screening intervals for diabetic retinopathy in patients with type 2 diabetes mellitus. JAMA 2000;283:889-96.
112. Scanlon PH. Screening intervals for diabetic retinopathy and implications for care. Curr Diab Rep 2017;17:96.
113. Modjtahedi BS, Theophanous C, Chiu S, Luong TQ, Nguyen N, Fong DS. Two-year incidence of retinal intervention in patients with minimal or no diabetic retinopathy on telemedicine screening. JAMA Ophthalmol 2019;137:445-8.
114. Scanlon PH, Aldington SJ, Leal J, Luengo-Fernandez R, Oke J, Sivaprasad S, *et al*. Development of a cost-effectiveness model for optimisation of the screening interval in diabetic retinopathy screening. Health Technol Assess 2015;19:1-116.
115. Lund SH, Aspelund T, Kirby P, Russell G, Einarsson S, Palsson O, *et al*. Individualised risk assessment for diabetic retinopathy and optimisation of screening intervals: A scientific approach to reducing healthcare costs. Br J Ophthalmol 2016;100:683-7.
116. Gulshan V, Peng L, Coram M, Stumpe MC, Wu D, Narayanaswamy A, *et al*. Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. JAMA 2016;316:2402-10.
117. Gulshan V, Rajan RP, Widner K, Wu D, Wubbels P, Rhodes T, *et al*. Performance of a deep-learning algorithm vs manual grading for detecting diabetic retinopathy in India. JAMA Ophthalmol 2019;137:987-93.
118. Dismuke C. Progress in examining cost-effectiveness of AI in diabetic retinopathy screening. Lancet Digit Health 2020;2:e212-3.
119. Ting DSW, Cheung CY-L, Lim G, Tan GSW, Quang ND, Gan A, *et al*. Development and validation of a deep learning system for diabetic retinopathy and related eye diseases using retinal images from multiethnic populations with diabetes. JAMA 2017;318:2211-23.
120. Xie Y, Nguyen QD, Hamzah H, Lim G, Bellemo V, Gunasekeran DV, *et al*. Artificial intelligence for teleophthalmology-based diabetic retinopathy screening in a national programme: An economic analysis modelling study. Lancet Digit Health 2020;2:e240-9.
121. Horton MB, Brady CJ, Cavallerano J, Abramoff M, Barker G, Chiang MF, *et al*. Practice guidelines for ocular telehealth-diabetic retinopathy, third edition. Telemed J E Health 2020;26:495-543.
122. Changing Diabetes Barometer Project-Goa. Goa: Directorate of Health Services, Government of Goa; 2014. Available from: http://www.nhm.goa.gov.in/images/uploads/Report_diab_2014.pdf%20. [Last accessed on 2021 May 17].
123. Kurji K, Kiage D, Rudnisky CJ, Damji KF. Improving diabetic retinopathy screening in Africa: Patient satisfaction with teleophthalmology versus ophthalmologist-based screening. Middle East Afr J Ophthalmol 2013;20:56-60.