Review

Mobile diabetes eye care: Experience in developing countries

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ABSTRACT

The prevalence of diabetes in developing countries is on the increase and along with it the need to provide structured care to avoid the feared long term complications among them loss of vision and blindness due to diabetic retinopathy (DR). The biggest hurdle facing most developing countries is the lack of resources and trained manpower to both screen and treat the large number of people with DR. Countries also face the additional problem of unequal distribution of resources between the urban and rural areas. To overcome these challenges models of mobile diabetic retinopathy screening and treatment aided by the use of telemedicine have been introduced and demonstrated to be popular and effective. The aim of this review article is to describe different mobile diabetic retinopathy screening and treatment models developed in India, which can be readily replicated in developing countries presented with similar difficulties.

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1. Introduction

An estimated 61.3 million people in India have diabetes and the number is projected to reach 101.2 million by 2030 [1]. Recent studies [2-4] have reported high rates amongst the rural poor, who often remain undiagnosed for long periods. Globally there are 366 million people currently known to have diabetes which is estimated to grow to 552 million by 2030 with 80% of all people with diabetes living in the developing world

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By 2030 the Indian sub-continent (South Asia) and China combined will account for almost half the global population of diabetes which will pose a huge challenge in order to provide reasonable quality prevention and care services. In chronic conditions apart from the disease characteristics per se, many socio-economic and health care delivery factors influence outcomes and economic costs [5]. People who are uneducated, unemployed, and those living in semi urban or rural areas who cannot afford or do not have access to basic health care, are likely to be diagnosed late and often already with diabetes related complications [6]. This has huge socio-economic significance, i.e. those who need more advanced/more expensive care for diabetes related complications, are often the ones who can ill afford and access such care. While some may be able to afford routine care, when burdened with complications requiring advanced expensive care – many of them borrow money and enter the debt trap with disastrous consequences to the individual, family and society [7].

Diabetic retinopathy (DR) develops in more than 75% of people with diabetes within fifteen to twenty years of diagnosis [8,9]. Recent studies from south India indicate a prevalence of 12–22% depending on the population sample and method of screening [10–13]. Some studies have reported even higher preponderance of DR in the rural population [11,12]. Conservative extrapolation from available epidemiological evidence indicates 8–10 million people in India may have some form of DR. DR is one of the leading causes of visual loss and blindness in the western world [14] and similarly in India it is an important cause of preventable blindness. Approximately 70% of the Indian population living in rural areas [15] has limited access to health care and a rising burden of diabetes. Despite improved understanding of the importance of early diagnosis and prompt treatment of DR, population based studies [16,17] in India estimate that only 18–35% of the diabetic population ever receives an eye examination. If access to eye care services is not made available, a large number of these people risk irreversible blindness due to DR. Therefore eye care infrastructure needs to be developed quickly to provide appropriate services to accommodate this large and ever increasing number of people with diabetes [13]. The situation is not very different in most developing countries, where in addition to infrastructure problem there is a great paucity of trained human resources to deliver eye care. Even where ophthalmologists are available medical or surgical retina training is not part of the regular ophthalmology residency training and only a few centers provide fellowship training programs in vitreo-retinal diseases [13].

3. Sankara Nethralaya Teleophthalmology Project (SNTOP)

The SN TOP model for DR screening was developed by Sankara Nethralaya, Chennai and supported by the WDF. A customized mobile van with an in-built ophthalmic examination facility with satellite connectivity provided by ISRO visits selected sites in Karnataka and Tamil Nadu. A social worker and an optometrist travel with the van [22]. Patients are initially screened in local camps where a preliminary ophthalmic examination is performed by the optometrist. After pupillary dilatation a single 45 digital retinal photograph centred midway between the disc and macula is taken. These images are converted to digital images in accordance with communications in medicine standards (DICOM) and transferred to the base hospital via a satellite link using VSAT (very small aperture terminal) hardware by store and forward technology. At the base hospital the ophthalmologist reviews the retinal images together with the clinical data and interacts with the optometrist and the patients by video-conferencing. Patients needing further investigations or surgical treatment are subsequently referred to the base hospital.

4. Aravind Teleophthalmology Network

This model was conceptualized by Aravind eye hospital, Madurai and supported by the WDF. Here also a customized mobile eye screening van fitted with VSAT connectivity provided by ISRO is used to screen people with diabetes in eye camps, hospitals and diabetes clinics [23]. An ophthalmic technician takes the retinal images using a special digital fundus camera. The retinal images are stored in a software-DRAGON (Diabetic Retinopathy Assessment & Grading over Network) specially designed for this purpose, along with the patients’ demographic data. Video conferencing facility is also available by which the retinal specialist at the base hospital can see and talk to the patient in the mobile van directly. These data are then transmitted to the Reading and Grading Centre at the base hospital in Madurai. At the reading centre the grader reviews these retinal images with the help of the software and classifies the severity of DR and suggests management strategies. The diagnosis and management advice is verified by a retinal specialist and sent to the van in a report format. At the van the report is printed and given out to the patient/doctor for further follow up. Patients needing further treatment are referred to the base hospital or to one of their satellite centres where such facilities are available.
5. MDRF/WDF Rural India Diabetes Prevention Project

Madras Diabetes Research Foundation (MDRF), in collaboration with the WDF runs a rural community outreach programme spanning 42 clusters of villages in Kancheepuram district of Tamil Nadu [24]. The screening for DR is done using a mobile telemedicine van equipped with satellite connectivity. The telemedicine van is equipped with a digital fundus camera with which retinal imaging is done and the images are transmitted via VSAT satellite connectivity provided by ISRO to their base hospital in Chennai. The retinal imaging is often done by the rural unemployed youth in the local population following suitable training. The ophthalmologist in Chennai interacts with the patients by video conferencing. Those patients with any form of DR needing further investigations or treatment are then referred to the base hospital in Chennai for further management.

6. Drishticare software

Since a large number of retinal images have to be reviewed by the retinal experts involved in large scale screening programs such as these, specific software, i.e. Drishticare has been developed [25]. The software uses a Web-based tele-screening framework and provides various fundus image analysis features within this framework. The patients are enrolled at the remote site and the retinal images are uploaded by the technician. Automatic image analysis is done to assess the quality of the retinal images and instant reimagining instructions are given to the technician if image quality is poor. Patient data are then transmitted to the Drishticare server via internet. An important feature of this platform is the introduction of a module at the server site that can upload and categorize case files as normal or abnormal based on image analysis. If the patient’s retinal images are normal with no evidence of DR then it is declared as normal and an automatic report is generated and sent to the remote site. Abnormal retinal images, i.e. with features of DR are further processed and sent to the ophthalmologist for opinion. With the aid of this technology the number of retinal images screened manually by the ophthalmologist is significantly reduced. Though this software promises to be a useful tool it still needs to be validated before it can be used extensively.

Models described above are excellent to screen large number of people with diabetes in rural and remote areas in resource poor settings, but they still do not solve the problem that those with proliferative DR still have to travel long distances in order to have treatment. Management of DR entails repeated visits to hospital eye clinics with multiple ophthalmic examinations and treatment sessions. Apart from the cost of actual care delivery, the overall cost to patients includes transportation, incidental expenses, loss of income due to absence from work for the patient and/or the attendant. This constitutes a substantial financial burden on the already stretched stretched and meager personal resources. Moreover, poor illiterate people from rural areas unaccustomed to city life feel overwhelmed when traveling to big cities for treatment, further constraining compliance and treatment adherence. Because of the need for multiple visits, screening patients in camps and referring them for treatment to a base hospital as done successfully for dealing with blindness related to cataracts is therefore unlikely to work as effectively for diabetic retinopathy, even if the treatment is offered free of cost. Therefore health care delivery models which provide screening, treatment and follow up closest to the patient’s familiar “home” environment are likely to be more successful. A significant hindrance to delivery of these services in rural and semi urban areas is the lack of trained manpower and equipment required to diagnose and treat DR. Given the relatively smaller number of cases at each rural center the economic viability of investment for expensive equipment to provide advanced care to relatively poor, non-affording and often uninsured rural communities is a challenge. In most developing countries out of pocket expenses constitute a significant part of health care costs and financing through public or private insurance is limited. For example 80% of health care delivery in India is through the private sector, but only a small fraction (less than 5%) of the Indian rural population is covered by health insurance which often may not pay for routine care for chronic diseases like diabetes [26]. At the same time health care infrastructure for diabetes care in the public system is inadequate and therefore the barriers to provide advanced diabetes eye care to this section of the population are enormous.

7. The Nayana Model

A model of distributive advanced outreach care designed and implemented to bring treatment of diabetic retinopathy literally to the patient’s doorstep in rural and semi urban areas of Karnataka, by the Vittala International Institute of Ophthalmology (VIIO) Bangalore and funded by the WDF is described below [27].

Nicknamed Nayana – beautiful eyes in Hindi, the specially designed advanced eye care treatment unit AETU van (Fig. 1) is custom built and carries its own 7 kVA generator, housed in a chamber within the van which powers the running of all the

![Fig. 1 – The Nayana AETU van.](image-url)
equipment, the air conditioning and dehumidifier when external power is not available. The cabin is hermetically sealed during travel. In addition to routine clinical furniture, the unit carries a funds camera with angiography and fundus photography facilities (Carl Zeiss Visucam Lite); a diode laser retinal photocoagulator (Carl Zeiss 532 S diode laser); B-scan ultrasound (Appasamy A/B scan); ultrasound biomicroscope (Appasamy UBM); visual field analyzer (Carl Zeiss Humphrey visual field analyser 720i make); applanation tonometer (Clement Clarke HS); pachymeter and YAG laser (Carl Zeiss Visulas Yag laser III). To protect the sensitive equipment from severe jerks and vibrations during travel, the equipment is disassembled and packed in custom made boxes with molded polyurethane packing including movement arrestors. During transportation the packed boxes are placed in a shock-absorbing floating cage – four large springs at its base and 7 other springs at the sides and top support the cage ensuring that the entire weight of the cage floats in air to prevent vibrations being transferred to the equipment (Fig. 2). The instruments are reassembled at each location and with experience can be done very quickly by the ophthalmic technician who travels with the van. Keeping in mind rare instances of anaphylactic reactions that may occur with fluorescein dye, the AETU van is equipped with emergency medical kit, a laryngoscope, Ambu bag and oxygen. During its field halt the van is stationed at or very close to a medical facility. An automated Dish antenna with the satellite transmitter is folded and fixed on the depressed roof of the van (HCL Comsat 1.8 metre motorized satellite antenna with GPS). When needed the antenna is lifted and connected to the base hospital through the satellite links provided by ISRO, enabling tele-consultations for second opinions (Bharat Electronics Satellite Modem, PolyCom Lite Video Camera). While this connectivity is useful, it was not deemed critical in the successful implementation of the project. Modern high speed mobile connectivity and video conferencing can prove to be as efficient. Widespread availability of cloud computing in the future will make it even better.

The Nayana Model differs from the earlier approaches in the basic premise that once a person with diabetes is identified to have sight threatening proliferative DR routine laser therapy should be delivered at the place where screening takes place thereby improving compliance and creating a patient centered service. The model can be applied both in situations where services of local ophthalmologists are available as well as in places where no local ophthalmologists are present. In the former case the AETU brings advanced equipment to local ophthalmologists who have been trained and empowered to use the equipment to provide eye care to people living within their area of practice. In areas where local human resources are not available the van is accompanied by qualified staff to deliver advanced care.

Where health care resources are limited a combination model based on the approaches described above where trained ophthalmic technicians take fundus photographs using mobile units which are downloaded and graded and subsequently qualified people come with a laser unit to deliver therapy can be used.

In the Nayana model 83 ophthalmologists with no previous specialist training or experience in medical and surgical retinal work, from 23 different locations in 13 districts of Karnataka on the pre charted route of the AETU were recruited. They signed a memorandum of understanding with VIIO Bangalore agreeing to comply with the protocol of care established for the project as well as to provide professional services at the agreed concessional rates and to treat patients earning less than 30S a month free of cost. Patients requiring advanced vitreo retinal surgical procedures were referred to the base hospital for surgical treatment.

All participating ophthalmologists underwent training in the diagnosis and management of diabetic retinopathy in a phased manner over 6 months, at VIIO, Bangalore; as well as on-site hands-on practical training in the mobile unit. Apart from the standard training protocol, participants received additional training tailored to individual needs based upon a self-assessment survey conducted prior to the training. The training sessions included seminars, continued medical education (CMEs) sessions and practical training, e.g., ophthalmologists first practiced laser on model eyes made of ping-pong balls giving them an idea of the power settings, spot size and duration of laser burns (photocoagulation). This was followed by performing laser treatment on patients with DR initially supervised by a trained retina specialist through the observer side tube of the laser machine.

**8. Raising awareness**

Whilst building and strengthening the capacity to deliver care, the project also implemented strategies to deal with the demand to enhance service utilization. This was done by organising educational sessions among the community health workers and local general practitioners (GPs) on the importance of good diabetes care and screening for complications.

![Fig. 2 – Equipment packed and suspended for transportation.](image-url)
Posters were put up at various locations including local clinics and pharmacies to increase awareness on the need for eye screening among people with diabetes and the project. Participating ophthalmologists encouraged local physicians and GPs to refer people with diabetes for screening. The project also received publicity in the local media and over time through word of mouth awareness grew. A fixed monthly route for the Nayana AETU van ensured that local ophthalmologist prescreened people with diabetes and those needing further evaluation or evaluation and treatment were given an appointment for the day Nayana visited their locality.

The targeted project area serves a population of 16.3 million people. Travelling 25 days every month the van visits 23 locations on fixed days across 13 districts covering a distance of 4500 km (Fig. 3). As of December 2010 the Nayana AETU van has completed more than 1300 days of operation covering over 200,000 km without a break. Twenty nine thousand people with diabetes have been examined, 1017 fluorescein angiograms, and 6998 laser treatments (Fig. 4) have been performed in the van. 513 sight restoring or sight saving vitreo retinal surgeries have been performed on patients referred to the base hospital, most of them either free of cost or at heavily subsidized rates.

8.1 Delivering advanced diabetes related eye care in the developing countries to address preventable blindness

The Nayana model has now been replicated in other WDF funded projects in India and abroad [28], notably in Thailand where two advanced eye care mobile units have been operating in parts of Northern Thailand (Fig. 5) under the auspices of the Ministry of Health and have achieved remarkable results [29]. Another WDF project in Kenya [30] is planning to apply the same model.

In resource poor settings delivering diabetes care is in itself a challenge let alone care for diabetes complications. The WDF over the last ten years has made a significant contribution to catalyzing action to change the situation. Apart from other areas of focus it has played an important role in stimulating action to address the problem of DR; funding not only traditional approaches to deliver care for DR but also nurturing bold and unconventional ‘out of the box’ approaches. Over the years WDF has funded over 49 projects in 20 developing countries that have screened 782,992 people with diabetes for DR, about 235,485 (30%) cases of DR detected of which 61,069 (26%) provided with sight saving laser therapy or surgery either free or at very low rates [27]. Many of these projects are still in the implementation phase and thus many more people with diabetes in remote areas will perhaps be prevented from the burden of blindness in the near future. While the numbers are impressive what is more important is that these projects have succeeded in creating innovative approaches where sometimes a confluence of technologies from era long past gone with the futuristic has taken place. Examples include using of cycle rickshaw mounted mega phone announcing an eye screening camp for people with diabetes at the village school on Sunday as well as advanced treatment units carrying sophisticated equipment with satellite enabled...
connectivity bringing the most advanced technology literally to the doorstep of rural poor many of them surviving on less than a dollar a day.

The Nayana model and other approaches described are not only examples of this convergence but also of building sustainable solutions by enhancing local capacity and skills through training and empowering ophthalmologists practicing in semi urban and rural areas to successfully provide hitherto unavailable services to their local communities at reasonable costs. For example in the Nayana project patients in the project area do not have to travel more than 50 km to receive treatment for DR; and they receive care and follow-up from a familiar doctor from the same area. These factors have improved compliance and the local ophthalmologists also benefit from the program. They now have a whole range of expensive ‘state of the art’ equipment at their disposal for 1 day in a month without the economic burden of paying for them. Their skills in diagnosing and treating medical retina cases has also greatly improved and they are able to retain a substantial volume of patients who previously had to be referred elsewhere, thus improving their practice and image. These ophthalmologists are in an unique position to form networks with local diabetes care providers thereby improving a multi-disciplinary team approach for comprehensive diabetes care.

9. Summary

While the different screening models for DR discussed above have enormous potential to reach out to the diabetic population living in remote and underserved areas of developing nations, the Nayana AETU model also provides treatment opportunities locally for those with severe forms of DR. By providing diagnosis and treatment of DR within a distance of 50 km of the patient’s residence, training of local ophthalmologists and sharing expensive equipment between them the described model offers opportunity to fill the gap between required and available services for DR. If the screening models for DR are linked to the distribute care model the effectiveness of both approaches will be magnified many times over and will bring quality care for people with diabetes and its complications to the local population at a relatively low cost.

Conflict of interest

The authors declare that they have no conflict of interest.

References


