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Mobile Teleophthalmology : A cost effective screening tool for diabetic retinopathy in rural south India

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Abstract

Diabetic retinopathy is a complication of diabetes that has been increasing at an alarming rate and is becoming the leading cause of blindness in developed countries. In India, the incidence of diabetes is increasing rapidly while the disparity in access to health care between urban and rural population creates the potential for disparate outcomes. Currently, few ophthalmologists in India have been trained in the diagnosis and treatment of diabetic retinopathy.

A model is herein proposed that utilizes mobile tele-ophthalmology in screening for diabetic retinopathy in rural south India. Mobile tele-screening technology with a satellite connection between the mobile van and the medical center enables, ophthalmologists to screen the rural population. This minimizes the number of unnecessary referrals to the main center for diagnostic investigation and treatment, and also reduce the cost of the screening program. Five districts in Karnataka state in south India are included in the projects with an estimated 12,500 diabetic retinopathy cases to be identified and treated in 5 years. The program also aims to spread the awareness of the condition and the need for early screening and treatment. Initial analysis suggests that the proposed model is cost effective when compared with the existing model for identifying diabetic retinopathy and screening large population in a short time.

Introduction

Diabetic retinopathy has been one of the leading causes of blindness in the developed countries. In India it was the 17th leading cause of blindness some 20 years ago. Today, diabetes-related blindness ranks 6th among causes of blindness in India. Screening for diabetic retinopathy saves vision at a relatively low cost. Such screening can be either ophthalmologist-based or ophthalmologist-led.

Mobile tele-screening is an ophthalmologist-led screening program that takes eye care facilities to the rural population. The technology makes it possible to provide mobile tele-screening with a satellite link to the central hub (main hospital), resulting in real time consultation and examination of the patients in rural villages. Patients are not required to travel to initiate eye care, and the ophthalmologist can effectively screen patients for various eye problems from his office in the main hospital.

Worldwide, the prevalence of diabetes mellitus, in particular type II diabetes, is rising at an alarming rate. The World Health Organization (WHO) and International Diabetes Federation (IDF) have estimated the number of adult-onset diabetes cases to more than double by 2030, from the current 171 million to 366 million cases.[1] In developed countries, the rate of increase is projected at approximately 42%, and in developing countries, particularly in India, it is projected at 150%. [1]

According to the prevalence of diabetes in India study (PODIS), a random multistage cross sectional population survey carried out in 108 centers, the prevalence of Diabetes using the WHO 1999 criterion is 5.6% in the urban Indian population and 2.7% in the rural population.[2] The demographic transition due to improved living conditions in rural India is associated with a three-fold increase in the prevalence of diabetes in the rural Indian population.[3] The prevalence of diabetic retinopathy in rural South India is 10.5%. Only 6.7% of individuals with diabetic retinopathy (DR) had previous ophthalmic examinations.[4]

The American Diabetic Association recommends annual dilated retinal examination. Delayed screening postpones the application of both medical and ophthalmologic therapies that are significantly more effective if applied at an early stage of retinopathy. To achieve near universal coverage, the screening method should be community-based, and the point of delivery should be within easy reach of the population.

In India, the ophthalmologist/population ratio is 1:107,000.[5] More than half the eye care facilities are in the private sector. Sixty-nine percent of the ophthalmologists are employed in the private and non-governmental sectors in urban areas. Five states (Maharashtra, Uttar Pradesh, Karnataka, Andhra Pradesh and Tamil Nadu) have almost 50% of the practicing ophthalmologists in India.[6] There is a wide disparity in access to ophthalmologists and dedicated eye beds across the country. The distribution of ophthalmologists favors urban over rural settings by a factor of ten.[7]

The number of ophthalmologists available is the limiting factor in initiating an ophthalmologist-based screening service in India. Because of this, the optimal screening model in India may be an ‘‘ophthalmologist-led’’ system. The technology to facilitate this type of service is telemedicine. Telemedicine includes the assessment and analysis of patient information and interaction by a health professional who is separated temporally and/or spatially from the patient.[8] Tele-consultations can be conducted in either real time (through video-conferencing) or by asynchronously, where the data are first captured and then sent back. The success of tele-consultation depends on the quality of connectivity between the central hub or main center where the ophthalmologist examines the digital data and the remote location where the patient is examined.[9] The mobile telemedicine system under review utilizes satellites or GSM (global system for mobile communications) technology to bring medical care to remote locations, including underserved rural areas, sites of major emergencies and areas of developing countries with a shortage of medical skills.[10]

The intervention discussed in this paper involves a mobile ophthalmic unit set up in a van. It has the necessary equipment for examination of the patient along with digital imaging technology and a computer system and a satellite link. Patients are examined with the help of the optometrist/technician trained in taking digital photography and processing of the images. The ophthalmologist, while sitting in the main hospital, reads the images and interact with the patient. The main hospital is linked via satellite to the mobile van. This system offers specialty services for patients who otherwise cannot access them.

The screening is traditionally carried out by a retina specialist or a general ophthalmologist for diabetic retinopathy. However alternative approaches include the use of other health care providers and use of retinal cameras. Studies have shown the sensitivity and specificity of retinopathy screening by optometrists, internists, diabetologists and nurses are highly variable in comparison to the retinal specialist.[11] The only alternative with sensitivity and specificity parallel to the rates with the traditional screening is achieved by use of retinal camera.[12]

Telescreening models for diabetic retinopathy are available worldwide. One is TOSCA (Teleophthalmological services citizen centered application), which provides DR screening services in Europe. Luzio et al. demonstrated the feasibility of electronic transmission of retinal images remotely using the TOSCA process.[13] Davis et al conducted a randomized clinical trial to evaluate the effectiveness of a telemedicine retinal screening program (TRCP) compared with usual care. TRCP used a non-mydriatic retinal camera located in a rural, federally funded primary care practice. The ophthalmologist located at the university center evaluated the retinal images and consulted with the patient using real time videoconferencing. The results reveal a six fold increase in participation rate of patients in the screening as compared with scheduled examination with other eye care providers.

Kawasaki et al[15] reported 92% of the diabetic patients were successfully evaluated for diabetic retinopathy using telemedicine as a screening tool. Tennant et al[16] advocated telemedicine for screening of DR. They used a Stereoscopic fundus digital imaging technology, and they were able to identify micro aneurysms, clinically significant and non significant macular edema, neovascularisation and intraretinal microvascular abnormalities with great precision. The findings in this study were confirmed by direct examination when the patient presented for treatment. Liesenfield et al[17] demonstrated 92% sensitivity and 81% specificity in identifying macular edema using two field 50° non stereo images in the study of telescreening of diabetic retinopathy.

Lee et al investigated various recruitment methods for community based screening for diabetic retinopathy and reported that the mobile, community based services increased recruitment and participation.[18] Marberley et al modeled the cost effectiveness of diabetic retinopathy screening by comparing traveling retinal specialists and retinal photography with a portable digital camera. They concluded that the retinal camera is a relatively cost-effective means of screening for diabetic retinopathy in isolated communities.[19, 20]

The cost-effectiveness of screening programs increases substantially if exams for diabetic retinopathy were combined with screening for other diseases that pose a risk to the same patient population.[21] Javitt et al[22-27] used a computer model, incorporating data from the various population-based studies and clinical trials from the multi-center studies to study the cost-effectiveness of detecting and treating diabetic retinopathy. The resulting analysis and projections indicate that preventive programs aimed at improving eye care for diabetic patients produce substantial savings. Hence, they are highly cost-effective health investments for society. Diabetic retinopathy screening is considered to be the most cost effective than any routinely provided health interventions for diabetic patients.

Mobile Teleophthalmology for Screening Diabetic Retinopathy

Recruitment of diabetics: Trained village level volunteers and social workers enumerate the village population for diabetic cases. This will involve eliciting a proper history. A registration desk at government hospitals registers cases for DR screening. The screening programs is advertised in the local newspapers and via posters in public places. The same information is also posted on the hospital's Web site. As part of Lions Club International Foundation diabetic retinopathy project, we have developed awareness posters, pamphlets and CDs. These resources are utilized to motivate diabetics to attend the telescreening program. All general practitioners within a radius of 25 km from the venue are approached to register their diabetics patients for the camp. Two sessions are held each week, each targeting 125 patients.

South India Vision network uses an ophthalmologist led model for screening for diabetic retinopathy. It is based on teleophthalmology. Relevant history, visual acuity, hand held slit lamp examination, recording of intraocular pressure by Tonopen, and acquisition of Digital retinal images are performed by a trained optometrist after dilatation using Topcon TRC-NW6S digital non-mydriatic fundus camera. The optometrist and the equipment necessary to conduct the tests are placed in a mobile van. The data and images are transferred to the hub i.e. Sankara Nethralaya Bangalore. A vitreoretinal surgeon reviews the pictures and data at the hub and gives advice regarding management. Information is transfered via through VSAT provided by the Indian Space Research Organization (ISRO).

All diabetics found to have retinopathy during screening are referred to the main hospital for the ancillary tests such as fundus fluroscein angiography and ultrasound. The ophthalmologist advises the patient on appropriate treatment, either laser photocoagulation or surgical intervention. All treatment is performed at the main hospital in Bangalore. Once treatment is complete, an appropriate follow up schedule with a fixed follow up date is given to the patient. A separate register will be maintained regarding follow up. A reminder letter is sent to patients who do not come for follow up.

Cost Effectiveness Analysis of Screening for Diabetic Retinopathy

Cost effectiveness analysis was performed to evaluate this model. Cost effectiveness analysis included the estimation of societal cost, including both direct and indirect costs for the various models. The two models that were used for comparison are the teleophthalmology model and the base hospital screening model.

In the base hospital approach the recruitment of diabetics for the screening is the same in both models. However, patients must be extra motivated to travel to the main hospital for screening.

The capital costs of the equipment involved in both models were annuitized and discounted at the rate of 5% annually. All the equipment is assumed to have a life time of 5 years and no resale value at the end of 5 years. These assumptions are made to facilitate calculations, as we had neither the exact life time of each piece of equipment nor the resale value at the end of 5 years.

For societal cost, we added lost wages for the patient and the accompanying attendant, assuming each patient had one attendant. Lost wages were based on per capita gross national income of India, $530 according to the World Bank.[28] If the patient has to travel to the main hospital it is assumed that he or she will lose the entire wage for that day. Patients who attend the screening at the onsite screening program or the teleophthalmology programare assumed to lose approximately 2 hours of wage. The maximum screening time in the case of telescreening program is between 1-2 hours. The main component of the screening time is the dilation time and time for registration. The actual screening time for diabetic retinopathy, which involves fundus photography and real time consultation with the ophthalmologist, is about 3-5 minutes. The maximum number of patients who can be screened in a given day is around 125 patients. So it is proposed to organize 2 screening camps in a week to screen 250 patients. The full program expects 12,500 diabetic patients per year. The recruitment of patients to be screened is expected to be the rate limiting factor.

Cost effectiveness analysis was performed based on the projected costs and based on the experience in conducting teleophthalmology programs during the last 2 years. From the available figures on cost we analyzed the cost per patient screened in each model. From the literature search, the sensitivity and specificity of the telescreening using 45° single field post mydriatic fundus photography with the Topcon TRC-NW6S digital non-mydriatic fundus camera[29] was 81% and 92%. We also estimated the costs by varying the prevalence of diabetic retinopathy from 15% to a maximum of 25% among the diabetics based on the prevalence reported in literature on south India. Two trained ophthalmologists screened the diabetics at the base hospital at the rate of 60 patients per day for 4 days in a week using Indirect ophthalmoscopy (Keeler Instruments Inc. PA, USA). Moss et al[30] reported that sensitivity and specificity of indirect ophthalmoscope for detecting any retinopathy was 82 % (95% CI 80-84) and 95% (95% CI 94-96). Neither model is used exclusively for screening for diabetic retinopathy, hence the entire costs were adjusted proportionately based on the number of days each model is used for screening. Most of the teleophthalmology programs are sponsored in part by the voluntary organization and local non-governmental organizations. They assistance in creating awareness and recruiting diabetics for screening and also arrange schools and halls

Table 1: Cost per case detected comparing various screening models from the facility and societal perspective

Facility perspective					
Prevalence		15%	20%	25%	Total cost per year
Telescreening without assistance	No-of cases	1519	2025	2531	
	cost per case	$31.60	$23.70	$18.96	$48,000
Telescreening with assistance	cost per case	$19.50	$14.62	$11.70	
Base Hospital	No-of cases	1,538	2,050	2,563	
	cost per case	$28.55	$21.41	$17.13	$43,900
Societal perspective					
Telescreening	cost per case	$49.77	$37.33	$29.86	$75,590
Base Hospital	cost per case	$106.06	$79.54	$63.64	$163,066

Note: Sensitivity and specificity of Telescreening model was assumed to be 81% and 92% & for Base Hospital model 82% and 95% respectively. Total number of diabetes to be screened = 12,500

for conducting the screening. Hence, the cost per case is reduced substantially from a facility perspective. Communication equipment and software are also provided free of charge by the ISRO which was established in 1969 as India's primary space research & development organization. The prime objective of ISRO has been to apply space technology in various national tasks. ISRO provides free satellite link to the base hospital and the mobile van. This was also taken into account in calculating the cost.

Results

Based on the preliminary cost effectiveness analysis, the cost per diabetic patient screened would be $3.51 with the Base Hospital model and $3.84 with the mobile Teleophthalmology model. This is the actual cost involved per case taking into account capital investment and management costs. We analyzed the cost per case detected in both models, assuming the sensitivity and specificity of telescreening to be 81% and 92% respectively. The prevalence of DR among the diabetic patients is reported to vary from 15% to 25% by different studies.[31] The cost per true case identified as diabetic retinopathy at 15% prevalence is $28.55 with the base hospital model and $31.60 with mobile teleophthalmology model. For various prevalence rates, the figures are estimated and tabulated in **Table 1**. With the increasing prevalence, the number of cases identified increases, thereby reducing the cost per case detected in both the models. However, the base hospital appears less expensive even at lower prevalence from the facility perspective. To equal the cost of identifying a true case by the base hospital, the telescreening should screen an additional 1350 patients. However, when teleophthalmology is supported by voluntary organizations, it becomes less expensive than the base hospital approach at all prevalence rates.

We also analyzed the cost per case detected from the societal perspective, taking into account the approximate cost by giving a dollar value to the time spent by the patient in both the models. We used per capita gross national income to calculate lost wages. Assuming 8 hours per day and 6 days in a week, estimate of each hour of lost wages equals $0.22 using per capita gross national income of India as $530. For the model involving teleophthalmology, we assume patients would lose 2 hours of wages on average. For the base hospital model, patients will be accompanied by the attendant and one full day of wages will be lost by both of them. The cost of other expense of about $1 was included for each person and attendant for food and other expenses. Travel expenses on average were estimated at $2 for each person. The final estimated cost per diabetic screened from the societal perspective is $13.05 and $6.05, the cost per true case identified is $106.06 and $49.77 for the base hospital and tele-screening model. The tele-screening has a considerably lower cost per case in comparison to the base hospital from the societal perspective.

Discussion

To evaluate a screening program one should look into the validity of the screening test in terms of sensitivity and specificity, the reliability, and the cost per case detected and coverage of the screening. Thus, the mobile telescreening model with a sensitivity of 81%, specificity of 92% it would cost $31.60 per case detected assuming a prevalence of diabetic retinopathy among the diabetics of 15% without any assistance from voluntary organizations. The telescreening model can be considered as an efficient screening model as it satisfies all the criteria. The success of telescreening depends on good coverage. As the services are taken to the community, patients are not required to travel long distances. In the current proposed model, steps are also taken to increase awareness about the disease which facilitates the success of the project. The base hospital has an advantage from an investment point of view. But, the coverage of the services to the rural population will be poor as the patients have to travel long distances, and they are not usually motivated to do so just for screening.

Telescreening is advantageous in screening for diabetic retinopathy among the rural population who do not have access to specialized eye care. For one time screening, this model is useful but the diabetic patients need to have a regular follow-up. We have not investigated the feasibility of repeated visits by the mobile van for the follow up.

In this model, the mobile van is utilized for providing primary eye care delivery to the rural population on non-screening days. The cost of setting up a dedicated and permanent teleophthalmology center for a specified population would be prohibitive. Depending on receptivity to the mobile services we can plan to have one mobile van for each district, and it would cover the entire district once or twice a year, and serve the entire population. Given the scenario of rapidly increasing prevalence of diabetes in India, screening and educating patients for early complications of diabetes like diabetic retinopathy can prevent needless or preventable blindness to a large extent. Similar models or modification to this model can be developed based on the initial results of the project, and can be implemented to cover the whole population of India.

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