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Telemedicine Applications for Screening Diabetic Retinopathy

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Abstract
Diabetic retinopathy is the most common cause of blindness in the world. Telemedicine is one of the best solutions for providing high-quality screening for many diabetic patients. This study was a systematic review, in which all published papers related to telemedicine application in retinopathy were reviewed during March 2001 to June 2017. Iranian databases (Irandoc, Barakat Knowledge Network System, Magiran and SID) and international databases (PubMed and Google Scholar) were searched with appropriate keywords. Out of the 59 articles retrieved in English, 11 related articles were identified and examined. Four articles focused specifically on the programs and applications for management of retinopathy, 6 papers on effectiveness and cost-effectiveness of this strategy, and 1 article on the satisfaction and collaboration of caregivers. Majority of the studies were concerned with economic impacts of telemedicine application in this area. Five studies examined the efficiency of telemedicine recruitment and patients' assessment and its ability to lower blindness occurrence. Telemedicine applications have been clinically validated and successfully implemented around the world. Low-cost and portable digital cameras are used in this approach. One of the benefits of this strategy is its high level of clinical accuracy, easy patient access, and cost-effectiveness.
Keywords: Diabetic retinopathy; Telemedicine; Tele ophthalmology

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Introduction

Diabetes is a chronic metabolic disease caused by insulin deficiency or insulin resistance. Insulin deficiency and insulin resistance lead to a lot of symptoms and serious long-term complications. Some of the major side effects are blindness, kidney failure, leg ulcer, amputation (due to peripheral neuropathy and peripheral vascular disease), myocardial infarction, and brain stroke.[1] Currently, chronic diseases have faced the world with serious problems. These types of diseases need more care than treatment.[2]

Diabetes mellitus (DM) is one of the main causes of death and disability in industrialized countries and the United States and one of the causes of the emergence of death in developing economies. Nearly 24 million Americans have diabetes, 5.7 million of whom have not been diagnosed, and 57 million other Americans have pre-diabetes. The prevalence of diabetes in 2010 was around 285 million worldwide which included 6.4% of the adult population in the world. By 2030, the number of people with DM will rise to 439 million.[3]

DM is a multifactorial metabolic disease characterized by increased blood-glucose level and metabolic abnormalities in carbohydrates, fat, and protein. The prevalence of diabetes in Iran is about 5.5% of the total population which is somewhat consistent with global statistics.[4] The prevalence of diabetes in Iran is 1.5% and 5.5% respectively for men and women.[5] More than 80% of the diabetes deaths occur in middle- and low-income countries. The

World Health Organization (WHO) has announced that diabetes will be the seventh major cause of death in 2030, of which 20% is related to the developed countries. Because of the many complications associated with this disease, there will be a heavy burden on the healthcare system.[6] According to a survey in 2014, the average per capita annual health cost for diabetes patients was $1205, and for patients with diabetes complications was $2276. The treatment cost in Germany and the United States has doubled, and in 2007, $174 billion was spent on diabetes treatment.[7]

Retinopathy is a chronic and threatening disease and has been clinically well-known in the world.[5] It is one of the main causes of visual disabilities and blindness in the world. In this disease, the micro vessels of the retina undergo gradual changes to such a degree that no perfusion is done to the retina. Therefore, the vascular permeability is increased, and vessels in the retina are abnormally proliferated in response to the lack of perfusion.[8] According to the WHO, the prevalence of diabetic retinopathy in the Eastern Mediterranean region is estimated to be in the range of 5% to 15%.[9] In the United States, about 28.5% of diabetic patients have diabetic retinopathy which is the main cause of severe and moderate loss of vision among adults at work age.[10] This disease is in the fourth place of the most common cause of blindness in the general population. However, among active adults in industrialized countries, it is in the second place.[7]

This complication causes an annual blindness in about 10 000 people. The probability of blindness in the people with diabetes is 25 times higher than that in non-diabetic patients. Many factors have been mentioned as risk factors for diabetic retinopathy in the people with diabetes. The most important of these are age, duration of diabetes, high blood pressure, smoking, inappropriate blood-glucose control, pregnancy, and high blood glucose levels.[11] Diagnosis and treatment of diabetic retinopathy in public health interventions play a key role in reducing vision loss. However, less than 50% of diabetic patients receive annual screening tests for diabetic retinopathy.[12,13] The main aspects of long-term care of the eye and prevention of vision loss in the patients with diabetes include the identification of specific retina injuries and, subsequently, the determination of the diabetic retinopathy severity. Traditionally, the pupil's eye dilation can be recognized through the individual assessment by experienced eye specialists. However, given that it is estimated that more than half a billion people with diabetes will need about 2000 eye examinations per minute by the year 2030, this retinal assessment approach is unlikely to be globally achievable by the healthcare system.[14] In addition, despite numerous worldwide plans to boost knowledge for eye examinations for all people with diabetes, only about 18% to 60% of the patients refer for eye examinations.[15]

Citizens are always considered as the ultimate goal of the service sector. Medical centers develop their goals to meet their needs and provide the most appropriate and fast services for them. The health system is not exempted, and it is a priority to provide appropriate and efficient services to the public in various health areas.[16] Today, information and communication technology play an undeniable role in public health and healthcare improvement. Telemedicine is a new method in medical, diagnostic and therapeutic care supported by electronic and communication processes, and provides access to health and treatment care in the areas where these services are not provided or are provided with limited capacity.[17] American Telemedicine Association (ATA) has defined telemedicine as the exchange of medical information through electronic communication devices to improve the health of patients. The word "Tele" refers to remote healthcare, which does not always include clinical services and may include videoconferencing, image transferring, remote monitoring of vital signs, medical education, nursing and contact centers. Telemedicine strategies for diabetic retinopathy are one of the most commonly used telemedicine programs for the eye. To make sure the accuracy of a remote medical imaging system for retinopathy, the quality of the images should be valid and comparable in the treatment of diabetic retinopathy and photographic standards (30 degrees, 7 context stereos, color, 35 mm slides).[3] The process of remote diabetic retinopathy screening is shown in Figure 1.

Methods

This was a systematic review study, in which all published papers related to the subject matter of the study were reviewed during March 2001 to June 2017. Irandoc, Barakat Knowledge Network System, Magiran, and SID

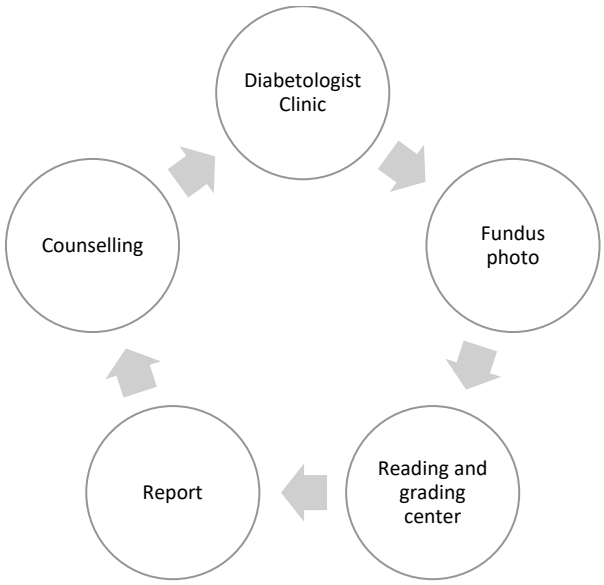

Figure 1. Diabetic Retinopathy Screening Process.

were searched for Persian papers, and PubMed and Google Scholar databases were searched for English papers. Out of the 59 articles retrieved in English, 11 related articles were examined.

Inclusion and Exclusion Criteria

The criteria for selecting articles were: being related to the research objective; articles that examined the role of telemedicine in the management and screening of diabetic retinopathy (time, cost-effectiveness, application, program, and satisfaction).

Article Search Strategy

First, according to the goal of the study (program, impact, time and cost of remote diabetic retinopathy screening), appropriate Persian and English keywords were searched as telemedicine, teleophthalmology, and diabetic retinopathy.

We first checked the titles of retrieved articles, then by matching the articles retrieved from different databases, duplicates were excluded. In the next step, the abstracts of the articles were examined, and unrelated articles were excluded. Articles were selected by 2 Health Information Technology (HIT) experts. Finally, 11 related articles were identified and reviewed (Figure 2; Table 1).

Discussion

In a study conducted on 89 diabetic patients, it was found that telemedicine screening was a reliable screening approach, and more than 50% of the patients were willing to use this method in next examinations.[7] Another study showed that remote care programs had not minimized blindness in the patients with diabetes. However, the implementation of remote diabetic retinopathy monitoring programs can improve the overall assessment of diabetic patients.[18] In contrary to the previous report, a study performed in remote screening care centers showed that the remote-based medical screening program is an implantable and efficient device for the diagnosis and treatment of diabetic retinopathy. Data suggests that remotely diagnosed diabetic retinopathy screening program is possible and justifiable to prevent blindness in diabetic patients, and integration of telemedicine screening is a collaborative effort between primary care physicians and ophthalmologists in timely and efficient screening and treatment.[9]

In a few studies, the results showed that all socio-economic costs of the telemedicine-based diabetic retinopathy screening model were significantly lower than the costs of a physician-based model, which is estimated $173 per person. In general, in many parts of the world, there is a strong logic for implementing telemedicine-based screening in terms of economic, social, and cultural aspects.[19,20] In a study, telemedicine led to an increase in diabetic retinopathy screening episodes and most of the participants did not need to refer to ophthalmologist, and their diabetic retinopathy level was stable over the course of the study.[12] In another study conducted by Mansberger et al, it was found that telemedicine increased the number of participants willing to participate in screening program using non-Fundus cameras rendering an effective method for screening the patients with diabetic retinopathy.[21]

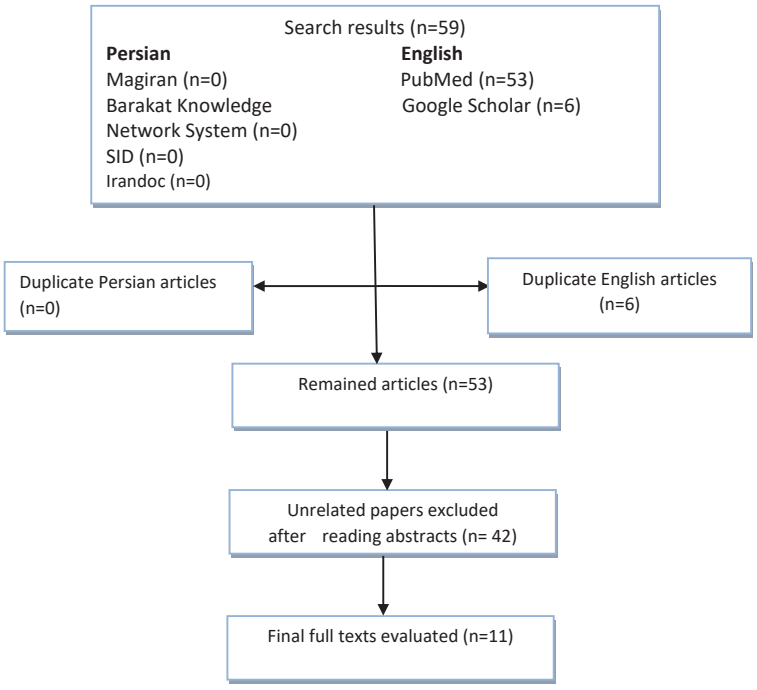

Figure 2. Search Flow Chart.

Table 1. Studies on the Telemedicine Approaches on Diabetic Retinopathy

Author/ Year	Type of Study	Data Collection Method	The Most Important Findings
Eszes et al[7]/2017	Pilot study	It Included Fundus screening and self-study questionnaire on participants' experience of Fundus examination (convenience, reliability, and interest in future participation) and also demographic and socio-economic factors.	Most patients were satisfied with screening, and this screening was reliable in their view; 67.3% were interested in being re-examined under a non-Fundus camera. There was a significant relationship between economic activity, education and marital status, and interest in future participation. Telemedicine can be a powerful tool to support ophthalmologists such that diabetic retinopathy screening is performed quicker and easier. The Fundus camera review is a quick, easy, and accurate alternative to the traditional, time- consuming, and "unacceptable" method.
Ting and Tan[18]/ 2012-2013	Cross-sectional		Despite increasing interest in new approaches to the evaluation of diabetic retinopathy through TELE in the last decade, no studies have proven that these remote care programs have minimized vision losses in diabetic patients. However, there is evidence that the implementation of remotely controlled diabetic retinopathy monitoring programs will improve the overall assessment of the patients with diabetes. In addition, it results in increased treatments and excellent compliance with referral recommendations. However, the clinical benefits and cost-effectiveness of these techniques are needed to improve overall visual and unknown outcomes and prospective studies.
Al Alawi and Ahmed [9]/ 2012	RCT	Six remote screening centers were established.	Centers equipped with Fundus cameras were created to take pictures of binoculars and send them over to the Internet for retina specialists at another center.
Nguyen et al[19]/ 2016	RCT	Creating a model at the Singapore Care Center	From the societal point of view, which includes all costs and effects, the diabetic retinopathy screening model based on telemedicine has significantly lower cost than the cost (saving a total cost of $173 per person) of a doctor-based model. Cost saving is $144 per person. There is a solid logic for making TELE-based screening everywhere in the world.
Mansberger et al[12]/ 2015	RCT	Participants were selected by screening at a primary care clinic using a non-Fundus camera (n = 296) or a traditional ophthalmologist together with a professional ophthalmologist (n = 271).	Telemedicine elevated the frequency of diabetic retinopathy screening tests, the majority of subjects did not need to refer to professional eye care centers and their diabetic retinopathy severity was stable throughout the study.
Mansbergr et al[21]/ 2013	RCT	Data were extracted from the patients in two clinics in India where diabetic patients were treated.	Telemedicine using non-Fundus cameras increased the proportion of participants. And most patients did not need direct examination by the eye care provider. The results showed that telemedicine may be an effective method for screening the patients with diabetic retinopathy and for referring them for further evaluation by the eye specialist. Many ways to reduce the poor quality of imaging can improve effectiveness.
Rachapelle et al[22]/2013	RCT	Data extraction from 5 outpatient care centers	Remote ophthalmology program is cost- effective compared to screening by specialists. If this screening is performed every 2 years it is cost-effective but if this happens annually, it will cost a lot.
Wilson et al[23]/ 2008	RCT	The project consists of 4 parts: registration, imaging, grading, and tracking/ reporting.	Average time to register, take an image and take eye pictures, is 00:12:53. A total of 76% of the samples for 1 year (with a retinopathy or a micro aneurysm) were consulted with their eye physician through telemedicine. Only 6 patients (0.8%) received a 6-week face examination (proliferative retinopathy or diabetic maculopathy). Retina screening software and its workflow process can be sufficient to overcome the challenges of providing screening services, and diagnosis is used for the people at risk for diabetic retinopathy.
Brady et al[20]/ 2014	RCT	Data extraction from an ophthalmic clinic	For this kind of screening, $36 per patient was spent. In a Monte Carlo simulation, it was shown that screening cost is $48 per patient. A significant burden of diabetic retinopathy was identified, most of which was not diagnosed. In a closed system, diabetic retinopathy screening through ophthalmology was considered for cost savings in a wide range of scenarios.
Rotvold et al[25]/ 2003	Pilot study	Conducting tests at the municipality of Altay, Norway	Ophthalmologists have found that retinopathy levels are measured faster with digital images. Seventy-six percent of patients expressed a high level of satisfaction with the examination with this remote ophthalmology. The evaluation results clearly showed that trust between healthcare personnel is important in creating positive attitudes.
Choremis and Chow[26]/ 2003	RCT		Most patients (83.6%) had type 2 diabetes. The average duration of the disease was 13.3 years. Fifty patients (about 6%) had severe ocular macular degeneration. Non-diabetic retinopathy was observed in 14.1% while proliferative diabetic retinopathy was observed in 15 (1.8%). Epinephrine mucous membranes (3 cases), macular cavities (2 cases), bilateral spinal cord (1 case), and retinal central venous obstruction (in 1 eye) were also observed. A total of 10% of the patients were transferred to a retinal specialist based on screen images. The resolution of the image was one of the main problems of the screening program. Overall, 35% of the graded images were in low quality, and 84.4% were poor. The quality of the images increased significantly during the study period. The images taken from patients >65 years of age were always poor in quality.

Another study showed that remote-vision ophthalmology is highly cost-effective compared to direct screening by experts. If the screening is done every two years, it is cost-effective but if this happens annually, it will have higher costs.[22] In a study conducted on 76 patients with diabetes, which consisted registration, imaging, grading, and tracking/reporting sections, the results showed that 76% of these patients could consult with an ophthalmologist indirectly and remotely, and about 8% of the patients needed to be examined directly, and 16% of them needed retest. The telemedicine-based retina screening program and its workflow process can directly reduce the challenges of providing screening services and can be used in diagnosis of the patients at risk for diabetic retinopathy.[23]

Mobile technology provides opportunities for further development of affordable applications, by remote evaluation of diabetic eyes using portable retina cameras, device-based smartphones, and telemedicine network. With remote ophthalmology, doctors can diagnose asymptomatic patients and stop or control the pathology before irreversible sight loss.[24] In a study on 42 diabetic patients, patients were asked to complete the questionnaire after telemedicine-based screening for diabetic retinopathy. In this study, 76% of the patients expressed a high level of satisfaction with this type of examination.[25] In another telemedicine-based screening program for retinopathy, non-diabetic retinopathy was observed in 117 eyes (14.1%) and proliferative diabetic retinopathy in 15 eyes (1.8%), and unexpected findings, including epinephrine mucous membranes (in 3 eyes), macular cavity (in 2 eyes), bilateral spinal points (in 1 patient), and central retinal vein occlusion (in 1 eye) were also observed. In general, only 10% of the patients were transmitted to retinal specialists based on screening images. The resolution of the image was one of the major problems in the screening program, which was the most common reason for poor-quality images. Images taken from the patients over 65 years of age were always poorer in quality than those taken from the patients under 65 years of age.[26]

Conclusion

The use of a remote ophthalmology approach to assess diabetic retinopathy with the goal of expanding the eye care standards and extending access to care, providing alternatives and appropriate methods of receiving and integrating diabetes eye care is inevitable in future medicine. Novel programs and interfaces have been created for interpretation, data collection, wireless transmission, and integration of electronic medical records. Many eye epidemic programs have been implemented for diabetic retinopathy screening around the world. Studies have shown that telemedicine-based diabetic retinopathy screening has led to overall improvement in diabetes screening and treatment, and prevention of vision loss caused by diabetes. However, diabetic retinopathy screening through telemedicine in remote areas can be very costly. Given the initial success of this program, a dramatic improvement in remote ophthalmology plans for screening diabetes in the future may be observed. Considering the further benefit of consolidating telemedicine programs for diabetic retinopathy, there is now a shift towards optimizing the method in regards to productivity, long-term outcomes and sustainability, quality assurance, patient care, and safety standards. Telemedicine for diabetic retinopathy programs has increased retinal evaluation rates in different diabetic populations, access to remote care in covered areas, and identification of critical clinical conditions with an urgent need for retinal evaluation with the goal of minimizing retinopathy. However, a remote diabetic retinopathy examination cannot be considered as a comprehensive alternative to the overall assessment of the eye. Therefore, telemedicine for diabetic retinopathy should be optimized by developing standard protocols, key quality standards, and new technologies to maximize the real-world outcomes.

Ethical Approval

Not applicable.

Competing Interests

Authors declare that they have no competing interests.

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