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Screening for Diabetic Retinopathy: Cost-Effectiveness Analysis of Direct Eye Examination
versus Telescreening in Rio Grande Valley, Texas

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An abstract of

A thesis submitted to the Faculty of the

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Abstract

Screening for Diabetic Retinopathy: Cost-Effectiveness Analysis of Direct Eye Examination versus Telescreening in Rio Grande Valley, Texas

By Fazila Aseem

Diabetic retinopathy poses a significant health concern in underserved and isolated, Hispanic-populated Rio Grande Valley, Texas. Hispanics have greater risk of contracting diabetic retinopathy compared to other races due to many reasons, including socioeconomics and behavioral risk factors. Diabetes is also significantly prevalent in Rio Grande Valley, increasing the risk of developing diabetic retinopathy among the target population.

Screening provides an effective way to reduce the burden of the disease. There are alternative methods of screenings for diabetic retinopathy: direct eye examination and retinal photography followed by necessary eye care and/or both, with tradeoffs to consider. Therefore, cost, access and quality concerns associated with different screening alternatives ought to be considered before implementing a strategy at population-level.

Rio Grande Valley's residents are dispersed and lack compliance to seek follow-up care. With higher prevalence, little access to preventive care, and greater cultural and economic barriers, finding cost-effective ways of reaching and screening diabetes patients in these Hispanic-populated regions is critical. By conducting a literature search and running a cost-effectiveness analysis of telescreening in primary care settings vs. direct eye examination by retina specialists, this study provides an economical model to enhance access to and quality of screening diabetes patients for diabetic retinopathy in Rio Grande Valley, Texas.

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CHAPER 1
INTRODUCTION

1.1 Introduction and Rationale

Diabetic retinopathy is the leading cause of blindness among American adults aged 20 to 74 (American Diabetes Association, 2013). According to the latest data, approximately 8 million Americans have diabetic retinopathy currently, indicating an 89% increase in the prevalence of the disease from 2000 to 2010 (PBA, 2012) whereas the number of diabetic retinopathy cases among 65 years or older is expected to increase from 2.5 million in 2005 to 9.9 million in 2050 (Saaddine et. al., 2008). This trend especially holds true for Hispanics who have the highest prevalence of retinopathy (8%) compared to whites (5%), blacks (5%) or other groups (4%) nationwide (PBA, 2012). Hispanics also have the highest prevalence of diabetes type 2, visual impairments and blindness (Cole, 2012). Therefore, heavily Hispanic-populated states, such as Texas, expectedly have greater prevalence of diabetes retinopahty compared to others. This study assesses the cost-effectiveness of screening for diabetic retinopathy in underserved and isolated, Hispanic-populated Rio Grande Valley, Texas.

Diabetic retinopathy poses a significant burden of health. Although many patients remain undiagnosed, in Texas alone 607,054 individuals 40 years and older (5.9%) are affected by diabetic retinopathy, posing a significant burden of disease (PBA, 2012). In addition to vision loss, adverse health conditions further compound disability among older adults; older adults with moderate or extreme vision loss are more likely to report diabetes, heart disease, stroke, and poor overall health (CDC, 2011). The total direct and indirect cost of visual impairments is approximately $139 billion nationwide (PBA, 2012). The cost of visual problems is particularly high in Texas, an estimated $10 billion annually, including $4,903 million in direct medical costs

and $5,096 million in indirect costs (PBA, 2012). With increasing prevalence of diabetes-related

visual problems in Texas and nationwide, addressing risk factors of diabetic retinopathy and

reducing the proportion of people with the disease is critical.

Some of the risk factors of diabetic retinopathy include socioeconomics such as financial

inability to seek preventive care, behavioral risk factors such as poor diet, and predisposition to

develop diabetes, such as greater genetic predisposition among Hispanics (Cole, 2012).

Hispanics also report the lowest access to eye health information, know the least about eye health

and are least likely to have their eyes examined (NIE, 2013). Additionally, 73% of Hispanics are

estimated to be overweight, and at increased risk for diabetes (Mary *et. al*., 2007 & CDC, 2011).

Many studies report that Hispanics lack the awareness of the US Dietary Guidelines, and suggest

encouraging dietary patterns that promote "nutrient and fiber-dense options" among Hispanics

(Horn, 2008).

To reduce the disease and its associated burden, and to address behavioral and social

determinants of health, there is a need for preventive strategies (technologies, policies, and

programs) that work. The process of determining what works, starts from basic research and ends

with implementation of effective interventions at population level. Basic research involves

identification of risk factors and the magnitude of their impact. As suggested earlier, not seeking

preventive care is one of the major risk factors of developing diabetic retinopathy. Once risk

factors are identified, potential interventions can then be developed. Screening interventions are,

therefore, tested for their efficacy and effectiveness. Once strategies are found to be effective, the

next step is to implement them among the general population.

A prevention effectiveness study of two preventive care services – telescreening and

direct eye examinations-- offered in Texas can be carried by modeling a previously established

study to determine which one provides maximum health outcomes at the lowest possible cost to the isolated Hispanic communities in Rio Grande Valley region. Preventive effectiveness analysis methods can be used to assess the impact of public policies and practices on health outcomes and gain insights regarding which strategy provides greater potential for reducing the burden of diabetic retinopathy and enhancing cost-effectiveness of health-care and public health systems in Rio Grande Valley, Texas.

1.2 Problem Statement

As discussed previously, diabetic retinopathy is prevalent and costly. Screening provides an effective way to reduce the burden of the disease. There are alternative methods of screenings for diabetic retinopathy: eye exam and portable retinal camera, with tradeoffs to consider. Current recommended preventive strategies for diabetic retinopathy include 1) screening, 2) retinal photography after which images are transferred to eye specialists for follow-up care, if necessary, referred as telescreening, and 3) comprehensive eye examinations by optometrists or ophthalmologists. Although widely practiced, the efficacy of screening as a part of multi-component primary care intervention at population level is debatable, depending upon how and by whom services are delivered (Chou, Dana & Bougatsos, 2010). Screenings by retina specialists such as via an eye exam, on the other hand, provide effective diagnosis and early intervention but are labor-intensive and expensive compared to screening interventions by other trained health personnel. Therefore, a prevention effectiveness study of preventive care services offered in Texas needs to be conducted to determine which service provides maximum health outcomes at the lowest possible cost to the needed population.

Telescreening is of special interest for screening diabetes patients in Rio Grande Valley. Hispanic populations are disperse and in remote areas of Texas, such as the borderline Rio Grande Valley. It is estimated that about 30% of Rio Grande Valley population have diabetes among whom more than 40% may develop diabetic retinopathy (Hidalgo County, 2011 & Shireman, P.K., 2012). With higher prevalence, little access to preventive care, and greater cultural and economic barriers, finding cost-effective ways of reaching and screening these Hispanic-populated regions for diabetic retinopathy is crucial. By comparing the cost-effectiveness of providing telescreening in primary care settings vs. direct eye examination by retina specialists, this study provides an economical model to enhance access to and quality of screening Rio Grande Valley diabetes patients for diabetic retinopathy.

1.3 Theoretical Framework

This study is guided by the theory of health economics, which suggests that scare resources are allocated among alternative uses for the care of disease and promotion, maintenance and improvement of health, including how healthcare and health-related services, their costs and benefits and health itself is distributed among individuals and groups in a society (World Bank, 2013). Considering the escalating costs of healthcare, this theory can be used to make choices among a set of alternative options that have similar outcomes with the aim to select an alternative that provides the greatest efficacy at the lowest cost—a cost-effective intervention.

Over the past several decades, the importance, effectiveness and value of prevention have been well-acknowledged (Haddix, Teutsch, & Corso, 2003, p. 306). However, preventive interventions are often constrained by limited resources. In this connection, prevention-effectiveness is the systematic assessment of the impact of public health programs and practices

on health outcomes by determining their effectiveness, safety and costs (Haddix, Teutsch, & Corso, 2003, p. 306). Assessing the impact of public health policies, programs and practices on health outcomes by determining their effectiveness, safety and costs via prevention effectiveness studies can help advance the field (Haddix, Teutsch, & Corso, 2003, p. 306).

Prevention-effectiveness pulls together information from epidemiological, public health surveillance, intervention studies and economic analyses to provide a scientific framework for recommendations regarding public health programs, guidelines for prevention and control, and decision-making about resource allocation. This way the concept can help guide decision-making to reduce the burden of many diseases, such as diabetic retinopathy, and enhance cost-effectiveness of healthcare and public health systems.

Prevention-effectiveness guides the development of the methods, analyses and conclusions of this study. Prevention-effectiveness framework helps direct the development of evidence-based guidelines via a systematic review, pulling health outcome and economic analysis studies from literature to provide a scientific basis for diabetic retinopathy screening practices, and guiding the adoption of a strategy that reduces the burden of the disease and increases cost-effectiveness of public health systems. Specifically, prevention-effectiveness in this study guides the assessment of diabetic retinopathy screening that provides maximum health outcome at the lowest possible cost in Rio Grande Valley, Texas.

1.4 Purpose Statement

The purpose of this study is to compare and evaluate eye care approaches, and propose a cost-effective model for the practice in Rio Grande Valley, Texas. The study aims to assess the cost-effectiveness of screening for diabetic retinopathy by telescreening and retina specialists in the isolated Hispanic communities of the region. The specific objectives of this study are:

I. To assess the net cost of telescreening in primary care settings compared to direct eye examination by eye specialists in isolated, Hispanic-populated communities of Rio Grande Valley.

Hypothesis 1: Telescreening and referrals in primary care settings are cost-saving compared to direct eye examination by eye specialists.

II. To assess the efficacy of seeking telescreening in primary care settings compared to direct eye examination by eye specialists in isolated, Hispanic-populated communities of Rio Grande Valley.

Hypothesis 2: Telescreening has comparable efficacy to direct eye examination with telescreening providing better sensitivity and direct eye examination better specificity.

III. To determine the additional cost required to prevent an additional case of diabetic retinopathy among the target population in a year. Individuals at increased risk for developing eye diseases will be referred for comprehensive eye examinations during preventive service visits, and the rate of follow-up compliance will be evaluated within a year after visits.

Hypothesis 3: The additional cost required to prevent an additional case of diabetic retinopathy among the target population using direct eye examination is comparatively high in isolated, Hispanic-populated communities of Rio Grande Valley.

1.5 Significance Statement

Diabetic retinopathy poses a significant health concern in Rio Grande Valley, Texas. Rio Grande Valley is predominately rural with an isolated and underserved Hispanic population, who are known to be at increased risk of developing diabetic retinopathy compared to other races. Diabetes, which is the primary risk factor for developing diabetic retinopathy, is also significantly high in this region compared to state and national levels. The combination of socioeconomics and behavioral risk factors, and predisposition to develop diabetic retinopathy among Hispanics calls for building cost-effective strategies to reach diabetes patients, provide necessary care to those in need, and prevent diabetic retinopathy and visual loss in general.

According to the literature, telescreening provides greater access, improved compliance among patients, and less costly means of screening for diabetic retinopathy. Evaluating the cost-effectiveness of this model compared to the traditional practice in Rio Grande Valley can help guide screening programmatic implementation. It is noteworthy to highlight that although this study assesses the effectiveness of this model for screening for diabetic retinopathy, the model can also be simultaneously utilized to prevent development and direct treatment of many other costly eye impairments, such as cataracts, glaucoma and blindness, in real settings.

In this connection, finding such cost-effective preventive strategies align with the Affordable Care Act (ACA). The results of this study can be used to guide lowering barriers to screening, create opportunities for screening for a large number of individuals who may not have access with the traditional method, maximize the use of limited ophthalmic resources while favoring multidisciplinary collaborations, and direct health policy decision-making in Rio Grande Valley, and at state and national levels.

1.6 Terms and Abbreviations

Diabetic Retinopathy (DR): The most common diabetic eye disease caused by breakage, blockage, or abnormal growth of blood vessels due high blood glucose content, causing gradual vision loss. The risk of the disease and extent of visual loss increases with the duration and progression of diabetes (NEI, 2013).

Comprehensive eye examination: A painless procedure in which an eye care professional examines eyes for common vision problems and eye diseases. The exam generally includes dilation, tonometry, visual field test and visual acuity (NEI, 2013)

Telescreening: Tele-ophthalmology during which retinal photography is obtained and evaluated by an ophthalmologist off-site. Patients are referred for eye examination, if necessary.

Incremental cost-effectiveness ratio (ICER): The ratio of additional costs to outcomes obtained when one intervention is compared with the next most effective intervention.

Decision Tree: A model of decisions and possible consequences, including probabilistic chance events, outcomes and costs.

CEA: Cost-effectiveness analysis

PDR: Proliferative diabetic retinopathy.

CSME: Clinically significant macular edema.

CHAPTER 2
REVIEW OF THE LITERATURE

2.1 Introduction

A literature review is conducted to synthesize previous research upon diabetic retinopathy health interventions, and facilitate understanding of the disease, and efficacy and cost of different interventions. Sources of information include recent and historical, nationally and globally conducted studies, vital statistics, and data from relevant agencies and organizations including, Prevent Blindness America (PBA) and American Academy of Ophthalmology (AAO). This chapter provides a summary of research studies and criteria for inclusion, gaps related to the target Hispanic population in Rio Grande Valley, Texas, and justification for conducting this project.

2.2 Literature Review

PubMed and EMBASE electronic databases were searched for articles, information and data published until December 2013. The specific objectives of this literature review was to assess 1) the net cost and 2) efficacy of telescreening compared to the traditional screening method, and 3) find secondary data sources for determining the cost-effective of this strategy in Rio Grande Valley, Texas. Titles, abstracts and full texts of the articles found through these searches were then screened for inclusion. Inclusion criteria for both data sources and study models were developed. Table 2.1 provides the inclusion criteria for secondary data.

Criterion	Description
Authority	Data used in this study are acquired from authoritative sources, including sites sponsored by relevant institutions and studies published in scholarly journals. Informal qualitative data from public websites, backed up by authoritative sources, are also used to tie the relevance of the published data to the target population of this study.
Accuracy	Accuracy of research methods, cited works and objectivity of information included in this study are considered for inclusion purposes.
Relevance	Since all disease and cost data for running diabetic retinopathy intervention programs in the isolated borderline Hispanic communities is not available in the literature, estimated costs are used from other sources such as state or national statistics to model cost-effective interventions for these specific communities. Therefore, data sources are included based on close relevance to Hispanic population in Rio Grande Valley, Texas.
Currency	Up-to-date information whenever possible. Article publication dates, currency of sources listed in the bibliography, and website updates are considered for obtaining up-to-date information for this project.

Table 2.1: Inclusion criteria for data sources

Health outcome and economic studies were reviewed to provide a broader overview of the efficacy and cost of implementing telescreening compared to traditional care in different regions. With a few exception, inclusion criterion for model studies is based upon Echouffo–Tcheugui *et. al.* (2013). The specific search criteria used to pull scholarly studies from PubMed

and EMBASE are included in Appendix S1. Table 2.2 and Figure 2.1 provide the selection

criteria and flow of model study selection, respectively.

Criterion	Description
Study type	Evaluated a real-world diabetic retinopathy screening program.
Program	Modelled for conducting telemedicine/telescreening.
Screening outcome	Reported the incidence/prevalence of diabetic retinopathy in relation to screening intervention(s).
Economic outcome	Reported costs of diabetic screening program(s).

Table 2.2: Inclusion criteria for study models
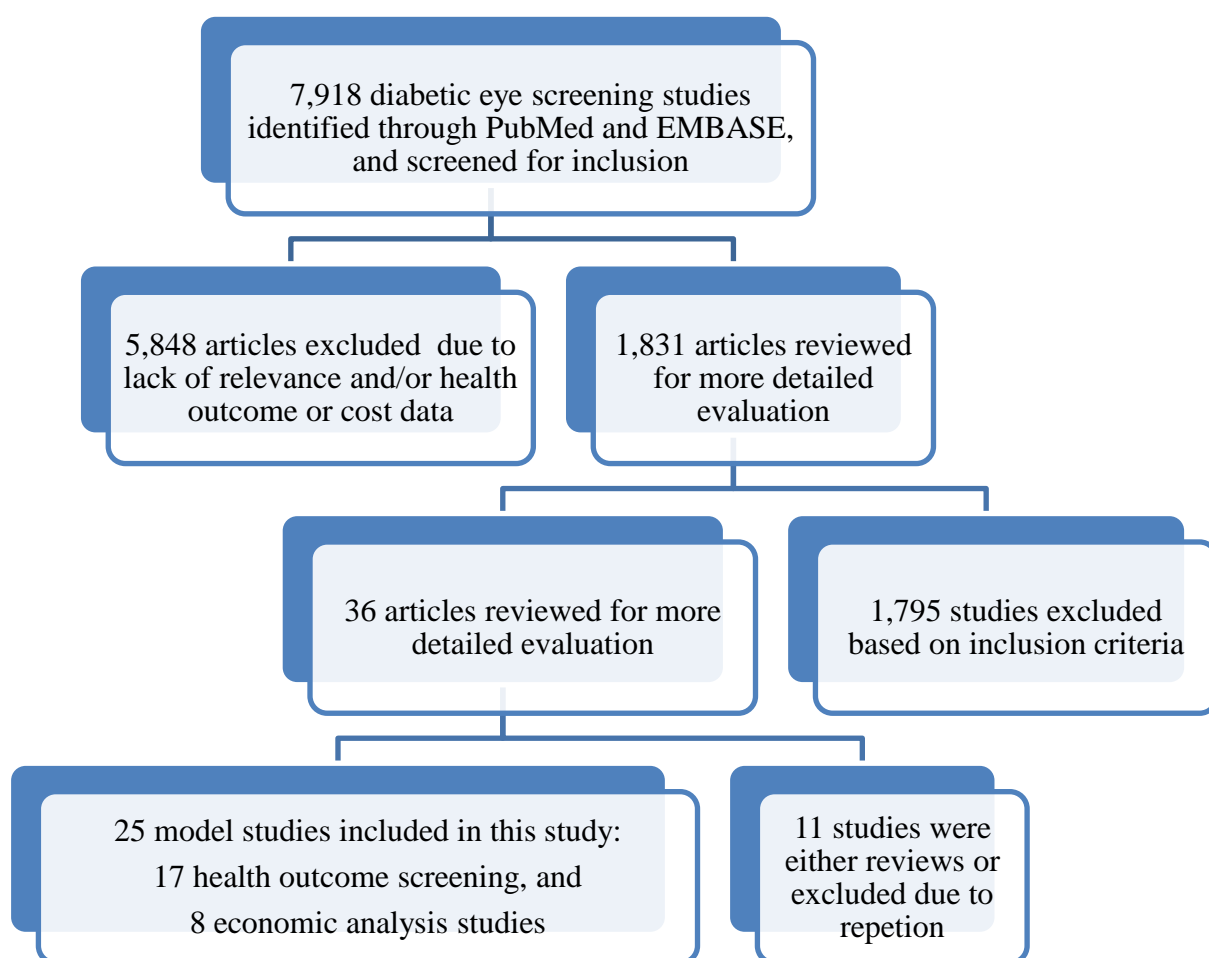
Figure 2.1: Flow of study selection

Model studies that evaluated screening outcomes and cost-effectiveness or cost-utility of various screening interventions according to the inclusion criteria were included in this study. Generally studies provided a good explanation of the model, along with the sources of data, outcome and cost measures. However, they differed in screening interval, frequency and perspective. To make it relevant to the target region of this study, special attention was given to the settings and locations where interventions were conducted. A brief summary of these studies is provided in Table 2.3 and 2.4, respectively.

Author & year of publication	Sample Size	Setting/location	Authors' conclusions
Hautala *et. al.*, 2013	14,866 images	Mobile eye examination unit (EyeMo)/ Finland	EyeMo is a feasible telemedicine model for screening diabetic retinopathy. Effective screening and timely access to care may reduce the rate of visual damage.
Kurji *et. al.*, 2013	57 patients	Multidisciplinary diabetic clinic/ Kenya	Diabetic patients preferred a tele-ophthalmology based screening over a traditional ophthalmologist-based screening due to its convenience, reduced examination time, and being able to visualize their own retina.
Schulze-Döbold *et. al.*, 2012	38,596 patients	Hospitals, primary care centers and prisons/ France	Telemedicine is a screening method that is well-adapted for diabetic patients, especially in light of increasing number of patients and decreasing number of ophthalmologists.
Xu *et al.*, 2012	562,788 participants	Rural region of Greater Beijing/China	Using telemedicine approach can be developed, applied and tested an infrastructure for ophthalmic mass screening of elderly inhabitants with a response rate of >80%.
Joshi *et. al.*, 2011	119 patients	Primary eye hospitals/ India	Telescreening provides a feasible framework to address challenges in large-scale screening. It offers a low-cost, effective, and easily adoptable screening solution through primary care providers.
Villena *et. al.*, 2011	1,311 patients	Hospital/Peru	A national screening diabetic retinopathy program should be considered for early detection and timely treatment.
Beynat *et. al.*, 2009	1974 patients	Rural orthoptics / France	Telescreening improved the quality of the ocular follow-up in diabetic patients in rural areas. However, management should be improved to lower costs.
Ng *et. al.*, 2009	5500 patients	Tele-ophthalmology assessment/Canada	Tele-ophthalmology decreases treatment time, allows following patients, prevents unnecessary referrals, and may decrease costs.
Boucher *et. al.*, 2008	3505 patients	Mobile imaging units/Canada	Mobile tele-ophthalmology imaging units efficiently lowered barriers to screening and increased access to individuals in increased need. It also maximizes the use of limited ophthalmologic resources, favoring multidisciplinary collaborations.
Massin *et. al.*, 2008	15,307 patients	Regional telemedical network/ France	Fundus photography combined with telemedicine has the potential to improve the regular annual evaluation for diabetic retinopathy.

Aubert *et. al.*, 2007	667 patients	Healthcare network/ France	Retinography with telemedicine obtained high quality screening for diabetic retinopathy that was at least as good as that obtained by using the classical ophthalmological screening method.
Taylor *et. al.*, 2007	293 patients	Primary care clinic/ TN, USA	Digital imaging technology in primary care centers significantly improve screening rates over conventional methods, increasing access to recommended diabetic eye care, and focus specialty care on patients with greatest need.
Liesenfeld *et. al.*, 2006	129 patients	Screening centers/ Germany	Telescreening for diabetic retinopathy is a valid screening method. Although biomicroscopy provides superior detection, retinography is almost comparable to traditional method.
Zimmer-Galler *et. al.*, 2006	2771 patients	Primary care centers/MD, USA	Implementation of the telescreening in primary care setting is practical and allows greater screening access.
Choremis *et. al.*, 2003	415 patients	University-affiliated hospital/ Canada	Despite the imperfections of such a system, telescreening provided favorable screening solution, allowing screening for large numbers of patients in a cost-effective and reliable manner.
Lee *et. al.*, 2000	1,197 patients	Community-based screening/Australia	Community-based telescreening increased compliance among diabetic patients to seek eye examination (from 55% to 70%), and can be used to encourage patients to get their eyes examined at the recommended intervals.
Lau *et. al.*, 1995	13,296 patients	Primary care clinics/Singapore	Non-mydriatic fundal photography provided accessible and effective diabetic screening, and is recommended for mass screening of diabetic eyes in communities.

Table 2.3: Summary of health outcome screening studies assessing telescreening for diabetic retinopathy

Author & year of publication	Sample Size	Setting	Perspective	Analysis design	Economic outcome	Authors' conclusions
Kirkizlar *et. al.*, 2013	900 patients	Medical Center/ CA, USA	Societal	Cost-effectiveness	Costs per QALY	Telemedicine is cost-effective for patient populations of >3500, patients aged <80 years, and all racial groups
Rachapelle *et. al.*, 2013	1000 patients	Rural camps & hospital/ India	Health care provider & societal	Cost-utility	Costs per QALY	Rural tele-ophthalmology program was cost-effective ($1320 per QALY) compared with no screening.
Richardson *et. al.* 2013		Rural health clinic/ VA, USA	Societal	Cost-savings	Costs per patient visit	Telemedicine yields a savings of $153.43 per patient visit.
Varela-Loimil *et. al.*, 2013	41,682 patients	Basic health care/ Spain	Provider	Cost-savings	Costs saved	Diagnostic agreement between primary care and specialized care was about 77%, and the minimum savings of direct costs were 136,145.97 €.
Li *et. al.*, 2012	611 patients	Community health center/ CT, USA	Healthcare systems	Cost-benefit	Costs per patient	Telemedicine-based diabetic retinopathy screening cost less ($49.95 vs. $77.80) than conventional retinal examination
Gomez-Ulla *et. al.*, 2008	6000 patients	Hospital / Spain	Healthcare systems & Patient	Cost-minimization	Costs per patient	Digital fundus imaging is expensive than direct fundus examination from healthcare perspective but is less costly from patient perspective.
Maberley *et.al.*, 2003	650 patients	Isolated community-based/Canada	Societal	Cost-effectiveness	Costs per QALY	A portable retinal camera provides a cost-effective means of screening for diabetic retinopathy in isolated communities of at-risk individuals.
Bjørvig *et. al.*, 2002	250 patients	Hospital and primary care/Norway	Societal	Cost-minimization analysis	Costs per patient	Telemedicine provides more expensive and cheaper service for patient workload of lesser and greater than 110 per annum, respectively.

Table 2.4: Economic analysis of telescreening for diabetic retinopathy

2.3 Summary of Current Problem and Study Relevance

Diabetes patients in Hispanic-populated Rio Grande Valley region have reduced awareness and lack adequate access to seek preventive eye care. Screening is recommended for all diabetes patients. However, only a small proportion of patients in Rio Grande Valley seek preventive care. Research studies consistency highlight lack of access to care and lower utilization of medical services among Hispanics compared to other racial/ethnic groups (Livingston, Minushkin & Cohn, 2008). Access to care and utilization of medical services is limited by a number of factors, including cultural and linguistic barriers, low insurance coverage and poor access to specialty care (Doty, 2003; Fernandez, Schillinger & Grumbach, 2004; Jacobs, Chen & Karliner, 2006; & Saha *et. al.*, 1999). Proposed theory-driven interventions, in this connection, should improve collaboration among organizational channels for better intervention outreach, and improve delivery and availability of services in a cost-effective manner in the region.

The majority of studies in the existing literature support telescreening as an effective preventive approach. Ng *et. al.* (2009), Hautala *et. al.* (2013) and Villena *et. al.* (2011) suggest that telescreening provides a feasible model for screening diabetic retinopathy, and timely access to care to reduce the rate of visual damage among patients. Boucher *et. al.* (2008), Choremis *et. al.* (2003), Schulze-Döbold *et. al.* (2012) and Taylor *et. al.* (2007) suggest that telescreening provides patients increased access, maximizing the use of limited ophthalmologic resources and favoring multidisciplinary collaborations. Kurji *et. al.* (2013), Lee *et. al.* (2000) and Xu *et al.* (2012) suggest that patients prefer telescreening over traditional care, increasing their compliance rates.

Aubert *et. al.* (2007), Liesenfeld *et. al.* (2006) and Massin *et. al.* (2008) suggest that efficacy of telescreening is comparable to the traditional screening method.

In light of intervention settings, Beynat *et. al.* (2009), Maberley *et.al.* (2003), Richardson *et. al.* (2013), Rachapelle *et. al.* (2013) and Xu *et al.* (2012) suggest that telescreening provides an effective means of screening for diabetic retinopathy in isolated and rural communities of increased-risk individuals, such as Rio Grande Valley. Additionally, many studies, including Joshi *et. al.* (2011), Lau *et. al.* (1995), Schulze-Döbold *et. al.* (2012), Taylor *et. al.* (2007) and Zimmer-Galler *et. al.* (2006) suggest that implementing telescreening in primary care settings is practical and effective.

As long as costs are concerned, Gomez-Ulla *et. al.* (2008) suggests that telescreening is cost-effective from patient perspective but expensive from healthcare perspective. Bjørvig *et. al.* (2002) and Kirkizlar *et. al.* (2013), on the other hand, suggest that the strategy is cheaper with increased number of patients and more expensive for smaller patient populations; the patient population sizes taken into consideration differ considerably though. The majority of studies, nonetheless, including Rachapelle *et. al.* (2013), Richardson *et. al.* (2013) and Varela-Loimil *et. al.* (2013), suggest that telescreening is cost-saving.

Although these literary studies provide supporting evidence for the cost-effectiveness of telescreening, differences between samples size, settings, locations, objectives and analyses of study models make it difficult to infer projected results for Rio Grande Valley residents. Economics studies are not in complete agreement about cost-savings of employing such a model. Additionally, many studies either evaluate

health outcomes or costs; only a few studies study cost-effectiveness of implementing

such a strategy at population level among risk groups.

Currently, literature lacks effective strategies to improve the cost, access and

efficacy of implementing such a large-scale screening program in Rio Grande Valley,

Texas. Considering capital costs, it is necessary to evaluate the cost-effectiveness of

telescreening in primary care settings in Rio Grande Valley in comparison to the

traditional screening method. Employing real demographic data, this study builds upon

the existing literature by evaluating the feasibility of telescreening framework to address

challenges in large-scale screening of increased-risk populations in isolated and

underserved regions of Rio Grande Valley. Additionally, this study can be used to guide

directing health policy decision-making in Rio Grande Valley, and at state and national

levels.

CHAPTER 3
METHODOLOGY

3.1 Introduction

In order to evaluate comparative cost-effectiveness of telescreening with the traditional direct eye examination, a literature review was conducted to synthesize health and cost outcomes of previous diabetic retinopathy telescreening interventions. Demographic and health data specific to Rio Grande Valley was then used to evaluate the cost-effectiveness of the two interventions. This chapter provides a summary of the type of research design used, a description of the population involved and rational for the selection of this population, programmatic activities included in the two interventions, plan for data analysis, and limitations and delimitations of conducting this study.

3.2 Population and Sample

Diabetes patients in Hispanic-populated Rio Grande Valley, one the most underserved regions in Texas, is the target population of this study. Currently, about 30% of Rio Grande Valley residents have diabetes (Shireman, 2012). Diabetes patients are at increased (more than 40%) risk of developing diabetic retinopathy whereas Hispanics generally have the the highest prevalence of the retinopathy (8%) compared to whites (5%), African Americans (5%) or other groups (4%) nationwide (CDC, 2011 & PBA, 2012). Hispanics also have the highest prevalence of diabetes type 2, visual impairments and blindness (Cole, 2012). Therefore, heavily Hispanic-populated regions, such as Rio Grande Valley, expectedly have greater prevalence of diabetes retinopahty compared to others.

Key determinants of diabetic retinopathy among Hispanics include lack of perceived threat of the increased risk of contracting the disease, lack of awareness regarding the importance of seeking preventive eye care, lack of access to preventive services, and financial concerns regarding seeking care. Hispanics report the lowest access to eye health information, know the least about eye health and are the least likely to have their eyes examined (NIE, 2013). An estimated 53% of Hispanics report "lack of eye problems" as one of the reasons for not seeking care (Trusty, 2001). This suggests lack of knowledge regarding eye care and perceived risk of contracting diabetic retinopathy among Hispanic populations.

Hispanics also lack adequate access to healthcare services. Research studies consistency highlight lack of access to care and lower utilization of medical services among Hispanics compared to other racial/ethnic groups (Livingston, Minushkin & Cohn, 2008). Access to care and utilization of medical services is limited by a number of factors, including cultural and linguistic barriers, low insurance coverage and poor access to specialty care (Doty, 2003; Fernandez, Schillinger & Grumbach, 2004; Jacobs, Saha, Komaromy, Koepsell & Bindman, 1999). Although the risk factors for contracting diabetic retinopathy and ways of seeking preventive eye care are well-studied, unfortunately many Hispanics remain unaware of it, which is the primary reason why 60% of diabetic retinopathy cases remain undiagnosed and undetected among Hispanics (NIE, 2013).

The location of Rio Grande Valley further hinders addressing these key determining factors to reduce the prevalence of diabetes retinopathy in the region. Rio Grande Valley is an isolated region, close to the border of Mexico. Therefore, a

considerable majority of Hispanic residents in Rio Grande Valley are illegal immigrants, which further complicates the situation and calls for a unique intervention for Hispanic populations residing in those regions. Since diabetic retinopathy is highly prevalent among diabetes patients and diabetes is the leading cause of blindness, it is utterly important for Hispanic populations, who are at increased risk of contracting diabetic retinopathy, to seek preventive care. The intervention strategies in this study are specifically modelled to address key determining factors, including lack of perceived threat and barriers to access, among Hispanic populations at the broader organization level in these regions.

3.3 Research Study Design

As noted in the introductory chapter, this study aims to assess the cost-effectiveness of screening for diabetic retinopathy by telescreening in primary care settings and direct eye examination by retina specialists in isolated Hispanic communities of Rio Grande Valley, Texas. The study question is:

What is the cost-effectiveness of screening an average-risk eligible diabetes patient for diabetic retinopathy using eye examination by a retina specialist vs. telescreening by a trained healthcare worker using a retina camera in Rio Grande Valley, Texas?

Study Format

The format of this study is model -- all relevant data is not available; secondary cost and demographic data is obtained from organizational, state and national sources whereas prevalence and probabilistic information is based on studies in the literature.

Due to absence of specific data, assumptions are made regarding cost and health outcomes of the program – the projected costs and outcomes from similar programs.

Using such a model is advantageous because it relies less on direct evidence and data can be pulled from different sources. It also saves time and simplifies reality. The disadvantage of using such a model is that it depends on estimated rather that true measured values. Therefore, accuracy of the model depends upon a researcher's supporting assumptions as described in the delimitations section.

Health outcomes

The immediate outcome of this study is the number of diabetes patients screened. Greater access can help increase screening among diabetes patients. Timely intervention can help detection of diabetic retinopathy and prevention of vision loss and even blindness. Therefore, the final outcome includes the number of diabetic retinopathy cases detected. The number of patients screened is a useful and reliable outcome to determine the final detection outcome.

Perspective

The study is conducted from a societal perspective to assess the cost of screening programs. Societal perspective provides the broadest perspective, including the healthcare costs of supervision, technical assistance and overhead to run the program as well patient costs.

Audience

The primary audience of this study include healthcare professionals in clinics, health departments and non-profit organizations (NGOs) screening Hispanic populations and diabetes patients at risk for diabetic retinopathy. Audience needs to know the cost,

sustainability and outcome measures for this study. These measures can then be used to compare the cost-effectiveness of the two intervention methods. The results of this study can also be of interest to local and state legislators for public health policy considerations.

Time Frame

The time frame of this study is a year – screening is recommended yearly and a year is also long enough to capture the extent of program costs and seasonal variation in programmatic activity. A year is also appropriate because funding agencies allocate funds on a yearly basis.

Analytic Horizon

The analytic horizon depends upon the outcomes of the study. If screened and the results are negative, then the person has to be tested every year – analytic horizon is 12 months. If screened and the results are positive, and the person is treated -- analytic horizon is lifetime.

3.4 Procedures

The two intervention strategies compared in this study are comprehensive eye examination and telescreening to screen diabetes patients for diabetic retinopathy. During comprehensive eye examination, an eye care professional examines eyes for common vision problems and eye diseases whereas telescreening includes retinal photography followed by evaluation by an off-site ophthalmologist. Patients are referred for comprehensive eye examination following evaluation, if necessary. Table 3.1 provides a list of activities included in the two intervention programs.

Activity	Description	Direct Eye Exam[1]	Tele- ophthal mology[2]
Patient Appt.	Schedule patient appointment.	√	√
Patient History	To understand eye problems and overall health. Info. asked includes any symptoms the individual is experiencing, any general health problems, family history of eye problems, medications taken and occupational/environmental conditions that may affect vision.	√	√
Preliminary Tests	To evaluate specific aspects of visual function and eye health such as depth perception, color vision, eye muscle movements, peripheral or side vision, and pupils' response to light.	√	
Visual Acuity	To evaluate how clearly each eyes see. Reading charts are often used to measure visual acuity and the results are reported in as a fraction such as 20/40 whereas normal vision is 20/20.	√	√
Refraction	To determining refractive error. Refraction determines the appropriate lens power needed to compensate for refractive errors.	√	
Keratometry	To measure the curvature of the cornea and the clear outer surface of the eye. The test is carried by focusing light on the cornea and measuring its reflection.	√	
Eye Health Evaluation	To measure eye pressure. Elevated eye pressure signals an increased risk for diabetic retinopathy and glaucoma. Evaluation of the lens, retina and posterior section of the eye may be done through a dilated pupil, which provides a better view of the internal structures of the eye.	√	
Eye focusing & movement	To assess accommodation, ocular motility and binocular vision in order to determine how well the eyes focus, move and work together. This is important for clear vision.	√	
Retina-Specialists	Screening images sent to volunteer ophthalmologists to make initial diagnoses.		√
Referral	Refer patients for supplemental testing, if needed.		√

Table 3.1: Intervention activities in retina-specialist eye exam and retinal-camera telescreening

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[1] Retina-specialist intervention activities are based on the recommendation of American Optometric Association: www.aoa.org

[2] Telescreening activities are based on Georgia Retinal Imaging Project (GRIP): www.preventblindnessgeorgia.org.

Cost Inventory

Since the study is conducted from a societal perspective, tangible costs directly related to implementing and running each program as well as intangible costs, with the exception of patient productivity losses, are included. In this connection, direct costs include medical, such cost of medical equipment, as well as non-medical costs, such as overhead costs. Since telescreening is conducted in existing primary care settings, many indirect costs involved are not included in this study. Table 3.2 and 3.3 provide tangible direct medical and non-medical costs, respectively.

Cost[3]	Retina-specialist direct eye exam	Retinal-camera telescreening
Personnel (wage, time) • Primary care physician • Specialist • Nurse • Technician	√ √ √	√[4] √[5] √
Equipment • *Tonometer* • *Reading chart* • Phoropter and Retinoscope • Computer stereo vision • Ophthalmologic Instruments[6] • Digital Camera	√ √ √ √ √ √	√ √
Medical Supplies • Ophthalmologic solutions • Drugs	√ √	√

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[3] Cost categorization is carried according to Maberley *et. al.* (2003).

[4] Not included in cost calculations; the program is run in existing primary care centers.
[5] Often labor without monetary exchange; economic cost is for patients who require additional follow-up care beyond imaging.
[6] A full listing of instruments is available at http://www.ophthalmic-instruments.org/.

Table 3.2: Tangible direct medical costs

Cost[7]	Retina-specialist direct eye exam	Retinal-camera telescreening
Clinic Property (e.g. rent)	√	
Transportation - To the clinic - To the primary center	√ √	 √
Administration	√	√
Overhead	√	

Table 3.3: Tangible direct non-medical costs

3.5 Data Analysis Plan

This study employs a cost-effectiveness analysis, in which net cost of an intervention is compared to its effectiveness in health outcome values – number of diabetic retinopathy cases detected, and life-years- saved. Using this type of analysis enables us to identify the most cost-effective prevention strategy in order to determine if a more expensive program is worth the additional cost; comparing the two interventions in terms of cost-effectiveness allows recommendation of a preventive intervention to healthcare providers and public health policy makers for programmatic implementation.

Adjustment for inflation

Costs are reported in 2013 dollars, using the latest data available for cost estimation purposes. Therefore, appropriate adjustments are conducted for inflation using a standard formula. This makes the costs of the two intervention programs comparable, negating any bias value.

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[7] Again, economic analysis of cost categorization is conducted according to Maberley *et. al.* (2003).

3.6 Limitation and delimitations

CEA can be used as a power tool to set priorities when resources are limited and help decision makers identify cost-effective strategies. It is more easily understood and easier to conduct -- no need to place a dollar or utility value on health outcomes achieved. However, this CEA also has some limitations.

First, due to absence of specific data, some assumptions are made regarding cost and health outcomes of telescreening in Rio Grande Valley – the projected health outcomes and cost from similar programs. Therefore, the accuracy of the model depends upon estimated measured values in the literature. Secondly, CEA requires a common health outcome measure and does not take into account multiple outcomes of an intervention. For instance, eye exams can prevent against other eye impairments, such as glaucoma and cataracts, but the CEA employed in this study does not account for those outcomes. Thirdly, although telescreening increases access to care, the CEA analysis conducted does not incorporate all of the values relevant to resource allocation decisions in public health, such as fair access to care, administrative feasibility, equitable distribution of limited resources, patients' rights to privacy and social justice. Therefore, besides the results of this study, other factors such as results from other perspectives and multiple outcomes should be taken into consideration before making policy decisions.
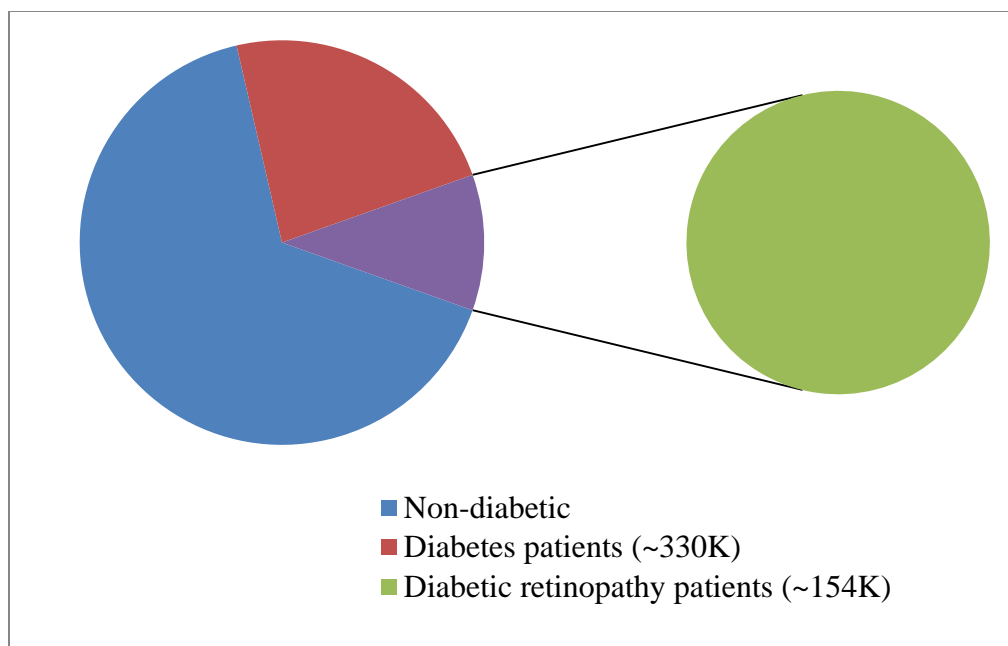
CHAPTER 4
RESULTS

4.1 Introduction

Literary studies suggest that telescreening in primary care settings, especially in rural and isolated communities, is cost-effective. However, studies differ in sample size, demographics, intervention locations, methodologies and analyses. Rio Grande Valley has unique demographics and the Valley's residents have a high risk of contracting diabetic retinopathy. Therefore, conducting a relevant study in Rio Grande Valley is crucial to help guide specific strategies. This chapter represents the results of the stated hypotheses and objectives of this study, and provides the major incremental cost-effectiveness of conducting telescreening compared to direct eye examination in Rio Grande Valley, Texas.

4.2 Findings

Health outcomes

Health outcome values for direct eye examination and telescreening alternatives are determined for Rio Grande Valley using literary estimates. Since the literature lacks current data for exact incidence and prevalence of diabetic retinopathy, the prevalence is estimated based on diabetes patient demographics in the region. An estimated 26% of Rio Grande Valley population has diabetes (Hidalgo County, 2011) whereas an estimated 46.9% of Hispanic diabetes patients develop diabetic retinopathy (Varma *et. al.*, 2004). Based on these estimates and Rio Grande Valley's demographic data according to the US Census Bureau, the expected number of diabetic retinopathy patients is determined (US

Census Bureau, 2010). A systematic estimation of prevalence of diabetic retinopathy in Rio Grande Valley is presented in Figure 4.1.

Figure 4.1: Estimated prevalence of diabetic retinopathy in Rio Grande Valley, Texas

As discussed in the methodology chapter, in this study, the number of diabetes patients screened is used as the intermediate outcome measure whereas the number of diabetic retinopathy cases detected using the two alternatives is used as the final outcome. The number of individuals screened is based on 26% and 65% access data obtained for traditional and telemedicine, respectively, during a telescreening project in South Texas (Shireman, 2012). The number of cases detected, on the other hand, is based upon the risk of the disease among diabetes patients and the reported sensitivity of telescreening (97%) compared to eye examination, assuming eye examination provides perfect sensitivity (Whited et. al., 2005 & Varma et. al. 2004). Rio Grande Valley demographic data is used to calculate regional outcomes. The intermediate and final measures for the two alternatives are presented in Table 4.1.

Strategy	Number of patients screened	Number of cases of diabetic retinopathy detected among those screened
Direct eye examination	85,453	40,077
Telescreening	213,631	97,187

Table 4.1: Approximate intermediate and final outcome measures

Economic outcomes

A decision tree for the two alternative strategies is completed, placing probabilities and outcomes on the tree for a yearlong study period. The final dollar amount of all the costs that occur on a branch and outcomes for each branch is then calculated. The probabilities and costs for various outcomes of interest are presented in 2013 dollar value in Table 4.2.

Costs for Various Outcomes	
Item	**Cost[8]**
Telescreening (includes cost for medical assistant, ophthalmologist, capital cost (equipment + training), equipment maintenance, and transportation fee)	U.S.$43.98 ($37–$55)
Direct eye examination (includes physician fee for bilateral eye examination, medical assistant personnel and round-trip transportation fees)	$77.07 ($57–$85)
Treatment of mild DR	$151.02 ($113–$169)
Treatment of moderate-severe DR	$254.91 ($190–$286)
Treatment of proliferative diabetic retinopathy (PDR)	$1651.54 ($1,234-$1,850)
Treatment of clinically significant macular edema (CSME)	$3388.76 ($2,531–$3,797

[8] Unadjusted rate ranges are based on Rein *et. al.* (2011)

Table 4.2: Cost of outcomes

      After constructing the decision tree with probabilities and outcomes and finding literature outcome costs, averaging-out-and-folding-back calculations on costs are performed, $\sum$(Pi * Ci)]; Pi-Probability; Ci=cost, to complete the tree. The information needed for this process is contained in the decision tree (i.e., probabilities, outcomes, and costs) provided in Appendix S2 whereas the calculated cost of branches and terminal nodes is provided in Table 4.3.

Box #	Description	Value ($)
1	Telescreening cost	43.98
2	Direct Eye Examination cost	77.07
3	Total patient treatment and follow-up costs using direct eye examination	477.06
4	Total patient treatment and follow-up costs using telescreening	339.67
5	Patient treatment costs after obtaining a positive image using telescreening	279.69
6	Patient treatment costs, following referral and reports using telescreening	273.36
7	Total treatment costs	399.99
8	Treatment associated cost with no-follow up or referral	0.00
9	Treatment cost of mild DR	151.02
10	Treatment cost of moderate-severe DR	254.91
11	Treatment cost of proliferative diabetic retinopathy (DR)	1651.54
12	Treatment cost of clinically significant macular edema (CSME)	3388.76

Table 4. 3: Decision tree calculated costs

The numbers in box 3 and 4 represent the expected values of direct eye examination and telescreening choices, respectively. In other words, the numbers in box 3 and 4 represent

the expected cost values of screening with direct eye examination and telescreening alternatives per person, respectively.

Cost-effectiveness comparison

In order to determine the incremental cost-effectiveness of the strategies, a table of incremental values is developed. The number of diabetes patients screened is based upon regional access values whereas the number of diabetic retinopathy cases detected is based upon the sensitivity of the two methods, assuming a constant number of patients is screened under both strategies. These cost, access and outcome data are presented in Table 4.4.

Strategy	Societal cost per 1,000 patients	Diabetics screened per 1,000 patients	Retinopathy cases detected per 1,000 patients
Direct Eye Examination	$477,064.07	260	469
Telescreening	$339,669.30	650	428

Table 4.4: Cost, access and outcome data

Using the information from Table 4.4 above, the incremental cost-effectiveness ratio (ICER) of the two strategies is calculated. ICER of telescreening is compared to eye examination using the following formula:

$$\text{ICER}_{\text{tele.vs eye exam}} = \frac{\text{Cost}_{eye\ exam} - \text{Cost}_{tele.}}{\text{Outcome}_{eye\ exam} - \text{Outcome}_{tele.}}$$

Assuming direct examination is costly and more effective, a summary of the ICER calculations is provided in Table 4.5.

Strategy	Retinopathy cases detected per 1,000 patients	Cost per 1,000 patients	Additional cases detected per 1,000 patients (A)	Additional costs per 1,000 patients (B)	Incremental CE Ratio [Costs per case detected] (B/A)
Telescreening	428	$339,669.30	-----	----	----
Direct eye examination	469	$477,064.07	41	$137,394.77	$3351.09

Table 4.5: ICER summary

4.3 Summary

Using demographic data and literary estimates for the efficacy of the alternatives, estimated health and economic data are determined, and a cost-effectiveness analysis conducted. The intermediate outcome of telescreening is higher compared to the traditional method; the number of diabetic patients screened is found to be about 214 thousand and 85 thousand using telescreening and direct eye exams, respectively. However, when the number of patients screened is kept constant, the final outcome is higher by direct eye exams; the number of retinopathy patients detected via telescreening and direct eye exams is found to be 428 and 469 per 1,000 patients, respectively.

The societal cost of conducting telescreening and direct eye examination is found to be $339,669.30 and $477,064.07 per 1,000 patients, respectively. Finally, the incremental cost-effectiveness of conducting telescreening in primary care settings compared to direct eye examination by retina specialists in Hispanic-populated Rio Grande Valley, Texas is found to be $3351.09 per diabetic retinopathy case detected.

CHAPTER 5
CONCLUSIONS, IMPLICATIONS AND
RECOMMENDATIONS

5.1 Introduction

Prevention-effectiveness studies provide a practical way to reduce the burden of diseases, such as diabetic retinopathy. In this study, cost-effectiveness analysis provides a simplistic means of comparing the net cost of two interventions, such as telescreening and direct eye examination, to their effectiveness, where effectiveness is measured in natural health outcomes. This chapter provides a summary of the study, discusses the findings, conclusions and implications of this project to current public health policy, and provides recommendations to help direct similar studies and guide health policy decision-making regarding diabetic retinopathy screening in Rio Grande Valley, Texas.

5.2 Summary of Study

Diabetic retinopathy poses a significant health concern in Hispanic-populated Rio Grande Valley, Texas. Hispanics have greater risk of contracting diabetic retinopathy compared to other races due to many reasons, including socioeconomics and behavioral risk factors. Diabetes is also highly prevalent in Rio Grande Valley, enhancing the risk of developing diabetic retinopathy among the target population.

Screening provides an effective way to reduce the burden of the disease. However, cost, access and quality concerns associated with alternative screening methods ought to be considered before implementing the strategy at population level. Current recommended preventive strategies for diabetic retinopathy include retinal photography screening and risk assessments by trained healthcare personnel, referred as telescreening

and comprehensive eye examinations by optometrists or ophthalmologists. Telescreening in primary care settings is of special interest for screening diabetics in Rio Grande Valley because Hispanic populations are disperse, in remote areas of Texas and lack compliance to seek follow-up care.

With higher prevalence, little access to preventive care, and greater cultural and economic barriers, therefore, finding cost-effective ways of reaching and screening diabetic patients in these Hispanic-populated regions for diabetic retinopathy is crucial. By conducting a literature search and running a cost-effectiveness analysis of telescreening in primary care settings vs. direct eye examination by eye specialists, this study provides an economical model to enhance access to and quality of screening diabetic patients in Rio Grande Valley for diabetic retinopathy.

5.3 Conclusions

The estimated health, economic and cost-effectiveness data of the two screening alternatives is determined using demographic data and literary estimates of the efficacy of the two strategies. The intermediate outcome of telescreening is higher compared to the traditional method; the number of diabetic patients screened using telescreening and direct eye examination is about 214 thousand and 85 thousand, respectively. This suggests that telescreening provides greater access to diabetic patients in Rio Grande Valley. This could be due to participants' preference for telescreening and/or the feasibility and convenience of conducing the screening at a primary care setting (Kurji *et. al.,* 2013; Lee *et. al.,* 2000 and Xu *et al.,* 2012; and Joshi *et. al.*, 2011; Lau *et. al.,* 1995;

Schulze-Dobold *et. al.,* 2012; & Taylor *et. al.*, 2007). Greater access due to telescreening then translates to greater detection of diabetic retinopathy cases

Keeping the number of patients screened constant, telescreening provides comparable efficacy to direct eye examination, with direct eye examination providing greater specificity (Aubert *et. al.*, 2007; Liesenfeld *et. al.*, 2006 & Massin *et. al.*, 2008). In this connection, the number of diabetic retinopathy cases detected by direct eye examination and telescreening is about 469 and 428 per thousand patients, respectively. This suggests that direct eye examination provides greater specificity.

The societal cost of conducting direct eye examinations by retina specialists is higher compared to telescreening in primary care settings. The total expected cost of treatment, detection and referral using telescreening is $339,669.30 per thousand patients whereas the value is $477,064.07 by direct eye examination. The results indicate a potential deviation from the conclusions of Gomez-Ulla *et. al.* (2008) that telescreening is cost-effective from patient perspective but expensive from healthcare perspective. According to this study, telescreening is cost-effective at all levels from a societal perspective in Rio Grande Valley.

The incremental cost-effectiveness ratio (ICER) of conducting telescreening in primary care settings compared to direct eye examination by a retina specialist in Hispanic-populated Rio Grande Valley, Texas is $3351.09 per diabetic retinopathy case detected. The additional cost needed per an additional case of diabetic retinopathy detected and treated via eye examination is comparatively high. Considering the magnitude of ICER, it can be inferred that telescreening potentially provides a cost-

effective strategy to screen for the disease. The value of ICER suggests that direct eye examination should be utilized only when resources are available and expendable. This conclusion aligns with previous findings that telescreening is cost-saving and should be utilized when resources are limited (Rachapelle *et. al.,* 2013; Richardson *et. al.*, 2013; & Varela-Loimil *et. al.,* 2013).

5.4 Implications

This study has important implications to encourage telescreening efforts in Rio Grande Valley, and help guide public health policies to reduce the impact of diabetic retinopathy in a cost-effective manner. In light of improved technology and collaboration among healthcare personnel, telemedicine provides a promising strategy to screen for diabetic retinopathy in the poor and underserved regions of Rio Grande Valley. Telescreening has the potential to address specific socioeconomic barriers and behavioral risk factors with lack of seeking preventive care among Hispanics in the region. By providing greater access and cost-effective outcomes, telescreening in primary care settings helps reach greater number of diabetes patients in Rio Grande Valley, provide necessary care to those in need, and enhance compliance with follow-up care, curtailing the impact of diabetic retinopathy and visual loss in the region in general.

Additionally, telescreening can also be simultaneously utilized to prevent development and direct treatment of many other costly eye impairments, such as cataracts, glaucoma and blindness, in real settings. The incremental cost-effectiveness ratio (ICER) determined through this study can be used to help decide resource allocation between current retina-specialist eye examination and retinal-camera screening

interventions. In this connection, finding such cost-effective preventive strategies align with the Affordable Care Act (ACA). The results of this study can, therefore, be used to guide lowering barriers to screening, create opportunities for screening a large number of individuals who may not have access to the traditional method, maximize the use of limited ophthalmic resources while favoring multidisciplinary collaborations, and direct health policy decision-making in Rio Grande Valley, and at state and national levels.

5.5 Recommendations

This study can be used as a power tool to set priorities due to resource limitation and help decision-makers identify cost-effective strategies. Based on this model study, telescreening provides greater access and is cost-effective compared to direct eye examination. Therefore, it is recommended that telescreening be implemented in Rio Grande Valley, Texas when resources are limited.

Before decision-making, however, the limitations of the literature review and cost-effectiveness analysis plan should be taken into consideration. This study employs a model format where literary estimates are used to drive results and conclusions. The study model is limited by the uncertainty in telemedicine costs and the rate of progression of diabetic retinopathy to high risk states. The costs of telemedicine in the region and rate of progression of diabetic retinopathy among Rio Grande Valley residents specifically may differ from the literary values, influencing the accuracy and applicability of the result of this study. Therefore, in order to reinforce the conclusions of this study, it is recommended that a retrospective and/or prospective study should be conducted to confirm the results.

Economic analysis conducted from other perspectives, such as provider and health care systems, should also be taken into consideration. Telescreening may be cost-effective from a societal perspective but perhaps not from another perspective, such as provider and healthcare. CEA does not incorporate all of the values relevant to resource allocation decisions in public health, such as fair access to care, administrative feasibility, equitable distribution of limited resources, patients' rights to privacy, and social justice. Loss of patient productivity is specifically, not incorporated into screening cost data obtained from the literature. The analysis also does not take multiple outcomes of an intervention into account. For instance, eye examinations can prevent against other eye impairments, such as cataracts and glaucoma, but the CEA employed in this study does not account for other outcomes. Therefore, besides the results of this study, other factors such as results from other perspectives and multiple outcomes should be taken into consideration before making policy decisions.

Also, advances in technology may modify quality of services and magnitude of costs. Conducting the study for a longer period of time, such as 5 years, on the other hand, may reduce the effect of capital costs. Additionally, administrative errors due to patient-reporting, such as delays from screening to treatment, and image quality issues that are included in the economic evaluation of this study may differ in other situations.

Despite potential limitations, this study successfully proposes a model for determining the cost-effectiveness of conducting telescreening in primary care settings compared to direct eye examination by a retina specialist in Hispanic-populated Rio Grande Valley, Texas. This model should encourage telescreening due to resource limitations, and help guide policy development to improve diabetic retinopathy detection

and vision loss prevention. Further collaboration is pivotal in helping embrace

telescreening in practice in order to seek better outreach, and implement cost-saving and

large-scale diabetic retinopathy screening in underserved, Hispanic-populated regions of

Rio Grande Valley, Texas.

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Appendix S1: Search terms and strategies

Medline via PubMed (from inception to until December 2013)
#1 "eye screening"
#2 "diabetic eye screening"
#3"diabetic eye screening prevalence"
4 "diabetic eye screening prevalence telemedicine"
5 "diabetic eye screening cost"
#6 "diabetic eye screening cost telemedicine"
EMBASE (from inception until December 2013)
#1 "eye screening"
#2 "diabetic eye screening"
#3"diabetic eye screening prevalence"
4 "diabetic eye screening prevalence telemedicine"
5 "diabetic eye screening cost"
#6 "diabetic eye screening cost telemedicine"

Appendix S2: A simplified yearlong decision scenario for diabetic retinopathy screening