A CLINICAL AND ECONOMIC PERSPECTIVE OF OPHTHALMOLOGICAL DISEASE IN RURAL INDIA

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Abstract

Background: Cataracts represent the major cause of blindness worldwide, disproportionately affecting such low-income countries as India. Accordingly, these cases are largely preventable, resulting in avoidable clinical and economic effects. **Methods**: This analysis consists of three parts: i) an exploratory systematic review of the literature to determine the extent to which the economic impact of blindness in India is known; ii) an epidemiological investigation of ophthalmological diagnosis in school age children in rural India; and iii) an examination of the determinants of cataract incidence and cataract surgical outcomes in a special Indian population through binomial logistic regression. **Results**: Cost estimates for blindness in India were $4.4 billion in 1997 – further investigation with current figures is needed. Costs also stem from more qualitative effects such as caregivers missing work as a result of depression. Vitamin A deficiency was not evident in school age children, though select ophthalmic diagnoses were associated with age and gender. In the adult population, determinants of cataract incidence included age, gender, occupation and caste, while surgical outcome was mainly dependent on occupation and severity of ophthalmic disease. **Conclusions**: The issue of blindness in India is multifaceted, and complicated by lack of knowledge of current prevalence. Further investigation into how select factors contribute to ophthalmic health, and into possible preventative strategies, is needed.

Keywords:
Blindness | Cataracts | India | Economics | Epidemiology | |Ophthalmology

Résumé

Contexte: Les cataractes représentent la principale cause de cécité dans le monde, affectant de façon disproportionnée ces pays à faible revenu comme l'Inde. Par conséquent, ces cas sont en grande partie évitables, entraînant des effets cliniques et économiques aussi évitables. **Méthodes**: Cette analyse se compose de trois parties: i) une revue systématique de la littérature exploratoire pour déterminer la mesure dans laquelle l'impact économique de la cécité en Inde est connue; ii) une enquête d'épidémiologie du diagnostic ophtalmologique chez les enfants d'âge scolaire en Inde rurale; et iii) un examen par régression logistique binomiale des déterminants de l'incidence de la cataracte et des facteurs participants au beson de la chirurgie pour la cataracte dans une population indienne spéciale. **Résultats**: Les estimations de coûts pour la cécité en Inde ont été de 4,4 milliards de dollars en 1997 - une enquête plus approfondie avec les chiffres actuels est nécessaire. Les coûts sont également associés avec des effets plus qualitatifs tels que les soignants manquant les jours de travail à cause de l'incidence de la dépression. Carence en vitamine A n'était pas évidente chez les enfants d'âge scolaire, mais certains diagnostics ophtalmiques ont été associées à l'âge et le sexe. Dans la population adulte, les déterminants de l'incidence de la cataracte sont l'âge, le sexe, la profession et la caste. Concernant les facteurs qui contribuent au résultat chirurgical, l'occupation et la gravité de la maladie ophtalmique étaient les variables les plus importantes. **Conclusions**: La question de la cécité en Inde est multiforme, et compliquée par le manque de connaissance de la prévalence actuelle. Une enquête plus approfondie sur la façon dont certains facteurs contribuent à la santé ophtalmique, et dans les stratégies de prévention possibles, est nécessaire.

Mots-clés:
Cécité | Cataractes | Inde | Économique | Épidemiologie | Ophthalmologie

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Firstly, I need to express the utmost gratitude to my supervisor, Dr. Raywat Deonandan, for his support, motivation, direction, and unwavering patience. His guidance was paramount to the completion of my thesis, and I am incredibly grateful to have had him as a supervisor. I would also like to thank my thesis committee members, Dr. Angel Foster and Dr. Anne Konkle, for their advice and insightful critiques.

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Preface

Statement of contributions

The content of this thesis could not have been completed without the assistance of several co-authors. To this end, I have outlined below the extent to which other individuals contributed to this thesis, as divided by article. I compiled all other portions of the thesis (that is, the general introduction, methods, and discussion) alone.

Article I – The economic impact of blindness in India

Amaal Popat was an independent rater for article search and selection for inclusion in the chapter. I performed a similar search, and then I synthesized the results and discussion that were included in the article.

Article II – The epidemiology of ophthalmological disease among school age children in rural India

This article used the data that I had cleaned and organized for later work in my thesis. I also contributed to the narrative of the introduction and discussion. I am second author of this article.

Clive Velkers performed the analysis of the data, the synthesis of the results, and the primary structuring of the article.

Article III – Determinants of ophthalmological health in rural India: an analysis of administrative and clinical data

I performed the entire contents of this article, including data cleaning, alone.

As my thesis supervisor, Dr. Raywat Deonandan provided guidance, direction, and editorial feedback throughout the entire thesis.

Ethics Approval

For the secondary use of a previously established database, the Health Sciences and Science REB, under the purview of the University of Ottawa Office of Research Ethics and Integrity, granted me approval to conduct my research as a student researcher, with Dr. Raywat Deonandan identified as the principal investigator. The file number associated with this approval is H02-11-08. A copy of the ethics approval form is attached in Appendix A.

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Chapter One

General Introduction

Introduction

As one of the largest countries in the world, both in terms of land mass as well as population, India is home to a great diversity of states, districts, ethnicities, languages, religions, castes, and tribes. According to the 2011 census, this diverse land is populated by over 1 billion people, of whom the majority (nearly 750 million) reside in rural locales (Census 2011). As a result, one of the main forms of industry in the country is agriculture, with roughly half of the population working in this sector ("India", 2015). And, members of the "lower" caste groups are performing most of this work.

Inherent in the Indian social structure is a system of castes: a regulated social community determined by birth. Indeed, many last names in India directly reflect the caste to which the individual belongs ("India", 2015). Generally, caste members are required to abide by specified rules in the social order, including marrying someone of the same caste, and pursuing certain occupations. Of the castes, the Scheduled Castes have borne historical social and economic hardships, and were formerly referred to as "untouchables" because of the impurities thought to be part of their lives ("India", 2015). The Scheduled Castes represent approximately 1/6 of the India population (roughly 166 million), and are principally occupied in the agricultural industry (as labourers, rather than owners) (Census 2011; "India", 2015). Of similar social status as the Schedule Castes are the Scheduled Tribes, the diverse array of India's tribal peoples, whose populations total an estimated 85 million (Census 2011). Social movements in relatively recent times have pushed for protection of these groups, however the social divisions still largely exist today (India, 1989).

Andhra Pradesh is the tenth most populous state in India, with nearly 85 million inhabitants (according to the 2011 census); of these, 55 million reside in a rural setting (Census 2011). Literacy rates in Andhra Pradesh fall below the national average, approximating 67% (Census 2011). Most commonly, the language spoken in Andhra Pradesh is Telugu, though much of the population also speaks Hindi, English, and/or Tamil (“Andhra Pradesh”, 2015). Andhra Pradesh also has a significant proportion of the population that belongs to the most disadvantaged castes, namely the Scheduled Caste (17.1%) and the Scheduled Tribe (5.3%) (Census 2011). Many residents of the state are employed in agricultural occupations, working as farmers, fishers, and in raising livestock. Indeed, 60% of the population reportedly is engaged in the agricultural workforce, and, in total, the agriculture sector accounts for US$8.6 billion of the state’s gross domestic product. Also majorly contributing to the state’s GDP are the service industry (US$21 billion) and the industrial sector (US$8.0 billion) (“Andhra Pradesh”, 2015). As a combined result of genetic and social factors (including occupational exposure to UV), Andhra Pradesh is heavily impacted by blindness, with the majority of these cases being preventable (Dandona, L. 2001).

In an attempt to address the needs of the blind population in Andhra Pradesh, the Srikiran Institute of Ophthalmology was founded in 1989 in Kakinada. The objectives of the organization include providing quality eye care and education to the principally poor individuals of the state (Srikiran Institute of Ophthalmology, 2009). These efforts also extend to community outreach programs in rural areas of the state's districts, offering screening camps to both adults and school-aged children. Treatments offered include emergency and outpatient services in addition to cataract surgeries, with approximately 17,500 surgeries being performed between 2002 and 2003 (Srikiran Institute of Ophthalmology, 2009). Over the past 16 years, Srikiran has been able to assist over 1.3 million outpatient individuals, and perform 1.4 million surgeries. And, more generally, the institute has the capacity to provide services to approximately 20 million of the residents of Andhra Pradesh (Srikiran Institute of Ophthalmology, 2009). To keep up with this immense quantity of patients, Srikiran has integrated software into its practice that can maintain various patient data.

Studies show that there are currently 38 million blind people in the world, of which it is postulated between 9 and 20 million are in India alone (Dandona, L. 2001; Venkatesh, R. 2005; Jose, R. 1997). This figure is rapidly increasing, with projections of the global prevalence of blindness estimated at 76 million by the year 2020 (Frisk, K.D. 2003). And, these figures are likely underestimates of the actual current situation based on the barriers blind persons face to seek or receive treatment. Majorly contributing to these figures are cataracts – the irreversible opacification of the ocular lens as a result of the denaturation of lens proteins – which constitute the leading causes of blindness worldwide and affect low-income countries in particular (Riaz, Y., 2009; Lindfield, R.

2008). Approximately 10 million cataract surgeries are performed every year, and yet this is not sufficient to meet current or future patients' needs – only 20-40% of needful individuals receive appropriate treatment (Vivekanand, U. 2005; Nanayakkara, S.D. 2009). Further, though research suggests the number of cataract surgeries in such low income countries as India appears to have increased in recent years, there has as-of-yet been evidence of a reduction in cataract-blindness – attributable to a backlog of patients, increases in the newly blind, and ineffective utilization of services (Venkatesh, R. 2005; Kovaj, V. 2007). Furthermore, it is clear that the outcome of these cataract surgeries is not ideal, and that training of many ophthalmologists is insufficient; numerous findings have revealed the outcome distributions for such procedures to be much poorer than those recommended by the World Health Organization (Lindfield, R. 2008; Resnikoff, S. 2004; WHO 1998; Nanayakkara, S.D. 2009; Special Report 2000; WHO 1997). As a result, researchers have called for increased work towards understanding these poor outcomes in order to better formulate strategies against avoidable blindness (Dandona, L. 2001). Smaller studies that have previously been undertaken have commonly had insufficient power to identify trends, or have only investigated a fraction of the explanatory variables that may be at play (Al-Shakarchi, F. 2011; Hatch, W. 2009). If the number of cataract operations are increasing, but the outcomes remain poor, then the burden of disease will remain unaddressed. Thus, more research on identifying factors contributing towards ameliorated patient health and successful outcomes will be essential to addressing the heavy burden that the blind bear (Thomas, R. 2005).

In order to begin reducing this burden, strategies against avoidable blindness in the forms of improved surgical outcomes, and the implementation of policies regarding health promotion, education, and prevention, will be invaluable (Dandona, L. 2001). Increased patient use of services will also be necessary, as will implementing programs to address the various barriers patients may face in seeking treatment; as previously noted, the population affected by avoidable blindness is severely skewed with age, occupation, and geographic origins playing the greatest roles (Riaz, Y. 2009; Kovaj, V. 2007; Theodoropoulou, S. 2011). Postoperative outcomes have also been loosely tied to such factors as low socioeconomic status and rural living. However, further investigation has been recommended to better understand these relationships (Al-Shakarchi, F. 2011; Ulldemolins, A. 2012). In order to make such decisions that affect the health systems, and in order to better monitor the current practices in order to improve clinical standards, a more thorough understanding of the factors that play into clinical outcomes, e.g. occupation, age, sex, and caste, will be vital (Lindfield, R. 2008; Limburgh, H. 2005). Putting these factors in context with the impact that blindness is having on affected individuals, namely on their economics and the extent to which they may contribute to mainstream economic activities, will elicit an improved comprehension of how best to distribute resources in order to maximize quality of patient care.

To this end, the present research has been undertaken with two key objectives:

1) Through a systematic review of the literature, summarize the extent to which the economic burden of blindness and visual impairment in India is known.
2) Through analysis of administrative and clinical data of a specific ophthalmology clinic, complete a retrospective cohort study to identify explanatory variables and their significance in ophthalmic pathology and outcomes of clinical intervention

Resultantly, the factors that contribute to good versus poor ophthalmology treatment outcomes may be elucidated. And, in viewing these results through an economic lens a more comprehensive conclusion may be drawn regarding how best to alleviate the impact blindness is having on individuals in India and the country as a whole.

Chapter Two

Methodology

Article I: The economic impact of blindness in India – a systematic literature review

In order to assess the economic burden of blindness in India, a literature review was undertaken. This review proceeded through a two-rater system, in order to reduce the possibility of bias. Both peer-reviewed and grey literature (i.e. non-academic publications in the form of such media as news articles) were included. However, no articles were uncovered through the searching of the grey literature. Through reading the article titles and research abstracts, studies were be assessed for their relevance to the research objective. Publications were included if subjectively deemed to be contain relevant information. Publications were excluded if they studied a country other than India, assessed quality of life only (i.e. without discussing economic effects), or were published prior to 1997. This cut-off date for the literature search was chosen for two reasons. Firstly, great economic reform had taken place in India during the early 1990s, the effects of which were especially felt through 1996-97 (Ghosh, A. 2006). Accordingly, it was deemed appropriate to ascertain the economic impact of blindness after this date, for it would be more currently relevant (compared to any research undertaken prior to the shift having taken place). Secondly, the most salient piece of literature concerning the economic impact of blindness based its conclusions on data drawn from 1997 and was published in 1998. Subsequent research based their findings on this work, and the majority of the literature use it as a reference. To capture the most comprehensive image of what is known about the current economic impact of blindness in India, it was necessary to include this paper and any similar papers, and thus set the cut-off date for 1997. After selection, information was extracted from each paper concerning direct effects of blindness on the Indian economy, costs for procedures that alleviate or prevent blindness, and such qualitative effects such as impact on caregivers. The references of each selected publication were also scanned for their potential relevance, resulting in a total of 16 articles that were included in the study.

Data Cleaning and Organization for Article II and Article III

As part of their administrative and registration processes, the Srikiran Institute of Ophthalmology collects a variety of information from their patients, including age, gender, caste, district of residence, etc. This institute operates a variety of services of individuals requiring ophthalmological consultation, including outpatient services, outreach camps to public schools, and base hospital surgeries. From the period of 1993-2010, these data were collected and input into Access Database for non-research purposes. In an attempt to better understand the population being treated by the Institute, and the successes being experienced therein, these data were obtained by my thesis supervisor, Dr. Raywat Deonandan, who then provided them to me for use in my thesis research.

In familiarizing myself with the data, it became clear that many patient records were missing demographic information, clinical information, or both. This rendered them impossible to study in any capacity, and the dataset had to be filtered accordingly. The types of information that remained allowed for the further investigation of two specific groups: school-aged children in the public school outreach camps, and patients being treated in the base hospital. These patients had outcome measures that could later be used in analysis, to determine what factors are impacting their ocular health. For the school-aged children, this included the diagnosis of a variety of ophthalmological diseases, while for the base hospital population this included presence of cataracts severe enough to require surgical intervention, and incidence of post-operative complications for those individuals that did undergo treatment.

In order to proceed with these investigations, the data had to be cleaned. Primarily, this involved running queries in access database to connect patient demographic variables with their clinical variables (that were housed in separate files). For the school-aged children, these were then extracted in excel format, and subsequently analyzed using SPSS. The base hospital population required more work. Firstly, patient files had to be separated running a secondary query that filtered between surgical and non-surgical cases. Whether patients required surgery or not could then be used as a dichotomous outcome measure. This was selected for analysis because of the robustness and completeness of the relevant dataset, and also because of the proportion of blindness (and preventable blindness) attributable to cataracts. Following this effort, the surgical cases were then cross-referenced with a dataset containing information on post-operative complications. Subsequently, patients were separated by presence or absence of such complications. Patient files were once again excluded from inclusion in the research if they were missing extensive demographic or clinical information. For all files, queries were run to detect the presence of duplicates, which, when present, were subsequently removed. The resultant files were exported in excel format and subsequently were capable of being analyzed in SPSS.

Article II: The epidemiology of ophthalmological disease among school age children in rural India

To glean a better understanding of the factors at play in ophthalmic disease for a youth population, which has largely been ignored throughout the literature, an epidemiological investigation was undertaken. Clinical and administrative data were obtained from the Srikiran Institute of Ophthalmology, and the analysis focused on the period from 2003-2010. The research focused on clinical visits to public schools, and accordingly the target population was aged 18 years and younger, and who had been screened for basic ophthalmic disease or injury.

To this end, disease prevalence was determined through the use of descriptive statistics. Bivariate statistical analyses (chi-square and independent samples t-tests) were used to determine relationships between demographic variables and clinical outcomes.

Note that this chapter has already been published in the Interdisciplinary Journal of Health Sciences (2014; 4(1):45-48). A letter from the journal's editor is included in Appendix A of this thesis ensuring that I have permission to reproduce it herein.

Article III: Determinants of ophthalmological health in rural India: an analysis of administrative and clinical data

To investigate the factors involved in cataract development and good surgical outcomes (as defined by the absence of post-operative complications), an analysis of clinical and administrative data from the Srikiran Institute of Ophthalmology was undertaken. Data were collected by hospital staff from patients needing ophthalmic consultation or treatment at the institute's base hospital, for the period from 1993-2010. Patient records were included in the research if they had complete demographic and clinical information, resulting in a population of 25,620 patient encounters to be investigated. The data were initially in Microsoft Access Database format, and were subsequently joined through the use of "queries" and converted to Microsoft excel flat files. These were then usable in statistical software-based analyses.

To determine the nature of the relationships between select demographic variables and patient outcomes, bivariate statistical analyses (in the form of chi-square and independent samples t-tests) were carried out in SPSS (Version 22). Based on these results, certain factors were chosen for further study if they were significant at the level of $p<0.05$. This involved running a binomial logistic regression, also in SPSS (Version 22). The details of this methodology are further elaborated in Chapter Five.

Chapter Three

The economic impact of blindness in India – A Systematic Literature Review

Authors: MacKenzie Turpin, Amaal Popat, Raywat Deonandan

Abstract

Objective: To determine the extent to which the economic impact of blindness in India is known.

Methods: A systematic review of the literature was employed, using a two-reviewer system. The Medline database was searched using terms: [“costs AND cost analysis” OR “health care costs” OR “cost of illness”] AND [Blindness/OR “preventable blindness”] and “India”; [costs and cost analysis” OR “health care costs”/ OR “cost of illness”] AND [Blindness/OR “preventable blindness”]; [Blindness/OR “preventable blindness”] and “India”; Economics AND [Blindness/ OR “preventable blindness”] AND “India”. Studies were included if they were written in either English or French and published 1997 onwards. Additional relevant papers were uncovered through systematic search of each selected publication’s list of references, and subsequently located through the PubMed database. To supplement the information gleaned from peer-reviewed sources, the grey literature databases Greynet and the New York Academy of Medicine’s Grey Literature Report were also searched as detailed above. Both qualitative and quantitative outcome measures were extracted.

Results: The search of the grey literature yielded zero (0) relevant results. The search of the other databases produced 380 articles (after the removal of duplicates). Through title and abstract review, 13 publications relevant to the objectives of this study were uncovered. Three (3) additional publications were included following a search of the initial papers’ respective bibliographies. Based on the prevalence of blindness in India cited in 1997, the economic impact of blindness in India was estimated at US$4.4 billion with the cumulative lifetime loss depicted at US$77.4 billion. Interestingly, US$52.5 billion of this loss is due to preventable or curable blindness, and US$22.2 billion stems from cataract blindness alone. Furthermore, the loss attributable to indirect effects, e.g. caregivers missing employment opportunities, was cited as US$0.70 billion. On the micro scale, household economies were adversely affected by blind individuals’ inabilities to participate in mainstream economic activities. In addition, the burden faced by caregivers lead to increased incidences of depression and resultant economic losses. A number of studies revealed corrective surgeries for avoidable blindness were able to alleviate the economic impact. Pediatric patients were afforded 50 productive, blindness-free years, and experienced a 21.9% reduction in lifetime medical expenses. Adult patients were able to reenter the workforce, and were able to regenerate the cost of their procedures within one year. The total review results were stratified based on micro- or macro-economic impacts, and tabled for ease of interpretation.

Conclusions: The economic impact of blindness in India is severe, and is worsening due to the rapid growth of blindness in the country; these impacts are experienced not only at the individual or household level, but extend to the national economy as well. One study suggested that at cost, if even 50% of patients with preventable blindness were treated the savings would be over US$1 billion, making this an important issue that needs to be addressed through proper policies and resource allocation.

Introduction

The current literature suggests there are currently 38 million blind people in the world – a figure which is expected to double by the year 2020 – of which between 9 and 20 million are in India alone (Dandona, L., 2001; Venkatesh, R. 2005; Jose, R. 1997; Frick K.D 2003). Many of these cases are in fact treatable or altogether avoidable; cataracts are the leading causes, a case that is particularly true for low-income countries such as India (Lindfield, R. 2008). In fact, based on the current predictors of life expectancy in the country, approximately 3-8 million people are estimated every year to become blind as a result of cataracts (Singh, AJ. 2000). This disproportionate prevalence in lower income countries simply adds to the burden these affected individuals must bear – a burden that takes a toll not only in individual households but also on the overall economy. Other countries have demonstrated the potential for improvement in economic productivity as a result of rehabilitating their blind population: computer-generated models in one study revealed that over a ten-year period in Pakistan, economic gains would total between US$707 million and US$4.9 billion (Awan, H. 2012). Such gains were based on the abilities of both patients as well as their caregivers to recommence mainstream economic activities (Awan, H. 2012). With such clear evidence of rapid and continued growth in the population of blind persons in India, an analysis of the effects of this blindness on the Indian economy is warranted. The effects may manifest qualitatively on household income, for instance as a decrease in working days of those who must stay home to care for the blind, as well as more quantitatively as a decline in national or regional GNP, due to healthcare costs and overall reduction in productivity.

With this study, we sought to review the peer-reviewed evidence to assess the likely impact of blindness in India on selected qualitative and quantitative micro- and macroeconomic indicators.

Methodology

Medline (principle source) and Pubmed (supplemental) databases were searched for peer-reviewed studies, while GreyNet and the New York Academy's Grey Literature Report were queried for grey literature. Two reviewers independently assessed articles for selection in the review. The search terms applied were as follows: [“costs AND cost analysis” OR “health care costs” OR “cost of illness”] AND [Blindness/OR “preventable blindness”] and “India”; [costs and cost analysis” OR “health care costs”/ OR “cost of illness”] AND [Blindness/OR “preventable blindness”]; [Blindness/OR “preventable blindness”] and “India”; Economics AND [Blindness/ OR “preventable blindness”] AND “India”.

Publications were included if subjectively deemed to contain relevant content. Publications were excluded if they studied a country other than India, assessed quality of life only (i.e. without discussing economic effects), or were published prior to 1997. These inclusion and exclusion criteria are summarized in Table 1.

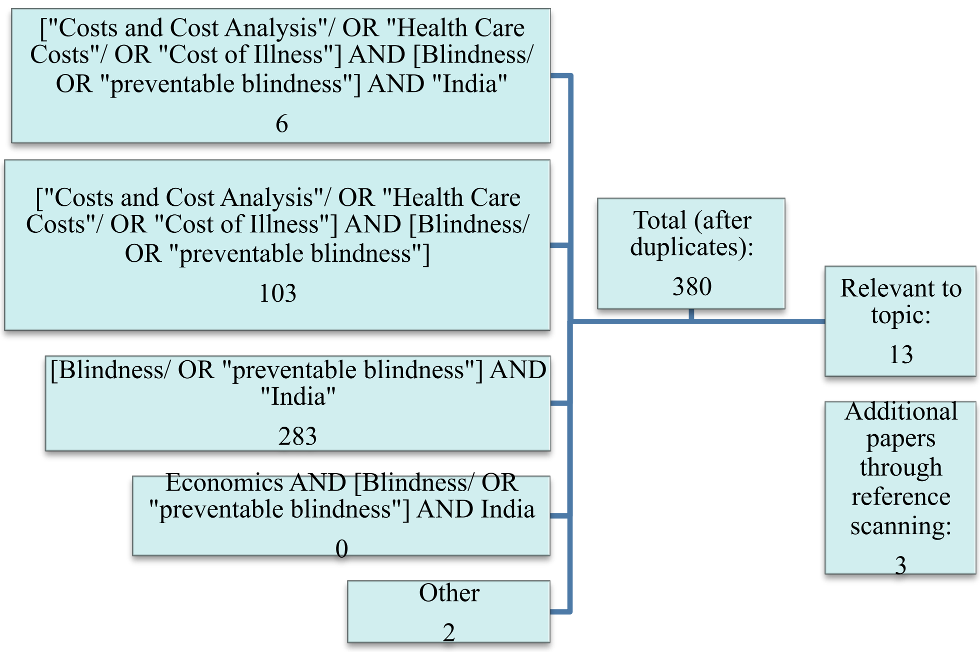
Table 1: Systematic review inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Published in English or French	Published before 1997
Focus of study in India	Focus of study outside of India
Focus of study on blindness and its associated economic impacts (qualitative or quantitative)	Focus of study on impact of blindness on quality of life only (i.e. outside scope of research)
	Focus of study on economic impact of other disease (i.e. not blindness)

Results

Our search of peer-reviewed literature produced 380 articles (after the removal of duplicates), while the grey literature search yielded no results. The selection process and results are summarized in Figure 1.

Figure 1: Flowchart of paper selection process



Additional papers were uncovered through systematic search of each selected publication's list of references, and were accordingly located through the PubMed database; this review garnered an additional three (3) relevant publications. After review of abstracts, thirteen (13) publications were determined to be relevant to the purposes of this review.

Relevant findings were extracted from each study and are summarized in Table 2.

Table 2: Summary of systematic review results

Study	Author	Year	Journal	Quantitative Economic Impacts	Qualitative Economic Impacts
Blindness and poverty in India: the way forward.	R. Khanna and U. Raman	2007	*Clinical and Experimental Optometry 60(5)*, 406-410		85% of males and 58% of females regained employment following cataract removal Patients regenerated 1500% of cost of surgery in first year
Burden and depression in the caregivers of blind patients in India.	P.S. Braich, S. Hollands, D.R. Almedia	2012	*Ophthalmology 119(2)*, 221-226.		Patients require more help with activities of daily living and close supervision. Both of these effects increase care burden, thereby augmenting risk of caregiver depression and decreasing household income.
Current estimates of blindness in India.	Murthy, G.V., Gupta, S.K., Bachani, D., Jose, R. and John, N.	2005	*British Journal of Ophthalmology 89*, 257-260		Age, sex, residence, literacy and working status associated with blindness – highest risk among those aged 70 and over and the illiterate. These people face higher economic burden.

Removal of avoidable blindness, our mission.	Kalam, A.A	2007	*India Journal of Ophthalmology* *55*(2), 91-93		Ratio of ophthalmologists to population is below world standard. Ratio of ophthalmologists to support staff also needs to increase
Cost-effectiveness of public-funded options for cataract surgery in Mysore, India.	Singh, A.J., Garner, P, and Floyd, K.	2000	*Lancet, 355*(9199), 180-184	Non-governmental hospital most cost-effective at US$54 per patient Ophthalmology "camps" very low cost option, but have higher rates of adverse outcomes: cost-effectiveness at US$97 per patient. State medical college hospital least cost-effective: US$176 per patient	
Economic Burden of Blindness in India.	Shamanna, B.R., Dandona, L., and Rao, G.N.	1998	*Indian Journal of Ophthalmology*, *46*(3), 169-172.	Total economic of blindness in India: US$4.4 billion in 1997 US$77.4 billion in cumulative loss over lifetime of the	

				blind Indirect loss (i.e. due to family members needing to care for the blind) estimated at US$0.70 billion Cumulative loss due to preventable or curable blindness for the lifespan of the blind ~ US$52.5 billion Cumulative loss due to cataract blindness over lifespan is US$22.2 billion	
What the comprehensive economics of blindness and visual impairment can help us to understand.	Frick, N.D.	2012	*Indian Journal of Ophthalmology, 60 (5)*, 406-410.		Blind or visually-impaired individuals have more limited opportunities to earn an income, further limiting their life choices – have different experiences with expenditures and health outcomes
Cost of pediatric cataract surgery in Maharashtra, India	Gogate, P., Dole, K., Ranade, S., Deshpande, M.	2010	*International Journal of Ophthalmology* 3.2 (2010): 182-6	Treating cataract blind children is costlier than adults - $122-	Pediatric patients require more follow-up which consumes

				$475 per eye. Cost of treating 50,000 pediatric cataracts is $20,000,000	resources
Measuring the burden of childhood blindness	Rahi, J.S., Gilbert, C.E., Foster, A., Minassian, D.	1999	*British Journal of Ophthalmology 83: 387-388*	Pediatric cataract surgery is much costlier than for adults but more cost efficient when you consider the reduction in blind person years	
Childhood cataract: magnitude, management, economics, and impact	Shammana, BR.	2004	*Community eye health 17.50:17-18*		Cataract removal in a child gives them 50 years blindness-free – can contribute to community
Simultaneous vs. sequential bilateral cataract surgery for infants with congenital cataracts: visual outcomes, adverse events, and economic costs	Dave, H., Phoenix, V., Becker, ER., Lamber, SR.	2010	*Archives in Ophthalmology 128: 1050-1054*	Reduction of 21.9% in lifetime medical payments for infants who receive simultaneous bilateral surgery for congenital cataracts	
The impact of successful cataract	Finger, R., Kupitz, D.,	2012	*PLOS One 7.8: 1-7*		Mean number of working household

surgery on quality of life, household income and social status in South India	Fenwick, E., Balasubramaniam, B., Ramani, R., Holz, F., Gilbert, C.				members /individuals engaged in income generating activities increases following cataract surgery. Successful treatment of cataract blind lead to higher monthly household income 1 year following surgery Number of individuals not working due to vision problems decreased
The socioeconomic impact of human immunodeficiency virus/acquired immune deficiency syndrome in India and its relevance to eye care	Murthy, G.	2008	*Indian Journal of Ophthalmology 56.5 395-397*	Costs of ARV pose serious barriers for blind to be able to afford surgery Blindness in HIV-positive persons reduces economic productivity and increases economic dependency → greater household expenditure	Screening services for avoidable blindness less available to HIV-positive individuals due to social isolation / ostracism Intersectionality – combined effect of HIV/AIDS and blindness acts disastrously on socioeconomic fabric

Blindness in the Indian state of Andhra Pradesh	Dandona, L., Donadona, R., Srinivas, M., Giridhar, P., Vilas, K., Prasad, M., John, R., McCarty, C., Rao, G.	2001	*Investigative ophthalmology and visual science 42.5: 908-916*	80% of blindness in Andhra Pradesh is treatable – poses unnecessary social and economic burden on society	Blindness due to uncorrected refractive error caused 30 years of blindness versus 5 years of blindness due to untreated cataract – avoidable years of cost
What is the global burden of visual impairment	Dandona, L., Dandona, R.	2006	*BMC Medicine 4.6*		Uncorrected refractive error most common cause of visual impairment – causes 14.9% of blindness in India Imposes a burden in more productive younger years of life – adverse socioeconomic impact
Economic cost of cataract surgery procedures in an established eye care centre in Southern India	Muralikrishnan, R., Ventaketsh, R., Venkatesh Prajna, N., Frick, K	2004	*Ophthalmic Epidemiology* 11.5: 369-380	PHACO and MSICS are sutureless surgeries that have limited restrictions on patients and little required follow-up – average patient costs US$12.37 ECCE IOL costs patients approximately US$19.85 – longer required length of stay,	Patients lose daily wages for surgery. Economic loss also incurred by close relatives/attenders that accompany patients to surgery and follow-up. Both need to pay for transport and food. Overall economic productivity loss was 2.5 times higher for patients undergoing ECCE IOL. In terms of total societal costs,

				more follow up visits	MSICS is the overall least costly cataract procedure

Discussion

A review of thirteen articles resulted in extracted insights into the likely economic effects of blindness on Indian society that can be grouped into five broad themes: macroeconomic impacts, household effects, the economic impacts of correcting blindness, the demographic and comorbid dimensions of blindness's economic effects, and the impacts of different treatment modalities.

Macroeconomic impact on the Indian economy

The study by Shamanna, Dandona and Rao most clearly identifies the macroeconomic burden of blindness in India: US$4.4 billion in 1997, with a cumulative loss over the lifetime of the blind estimated at US$77.4 billion (Shamanna, BR. 1998). This study also reported the indirect losses incurred due to blindness – for instance due to family members missing out on employment opportunities due to their obligations to care for blind dependents – as US$0.70 billion (Shamanna, BR. 1998). The investigators further estimated the cumulative loss due to preventable or curable blindness at US$52.5 billion over the lifespan of blind individuals, with US$22.2 billion alone stemming from cataract blindness (Shamanna, BR. 1998). From these findings, two things become clear. Firstly, on a macroeconomic scale, blindness is incurring major losses in India and is degrading the socioeconomic fabric. Secondly, most of the figures are derived from one study dating back to 1997. With rates of blindness steadily increasing – a fact that is especially true in India, which has a disproportionately affected population due to a combination of genetic history, environmental influence, and other factors – these figures are certainly an underestimation of the current state of blindness and the associated economic status in the country.

Household effects

On a microeconomic level, especially in terms of qualitative effects within the household, there were a greater number of relevant studies. One such study determined that because blind individuals require close supervision and more help with activities of daily living, then caregiver burden was greatly augmented and led to increased incidence of depression (Braich, PS. 2012). Resultantly, these caregivers were unable to participate in productive economic activities, and household income was decreased.

A similar study investigated the proportion of individuals that were able to return to work following their blind dependents' corrective surgeries (in this context, cataract removal) (Finger, R. 2012). After the affected individuals underwent cataract surgery, the mean number of working household members (i.e. individuals engaged in income-generating activities) significantly increased (Finger, R. 2012). At the one-year follow-up, the successfully treated individuals' households experienced higher monthly incomes, and the number of individuals not working due to vision problems had markedly decreased (Finger, R. 2012). Khanna and Raman determined that through regaining employment following cataract removal, patients were able to regenerate 1500% of the cost of their surgery in the first year alone. However, the study did highlight a discrepancy between males and females in this effort: while 85% of males regained their employment, only 58% of females were able to do so following cataract removal (Khanna, R. 2007).

Economic effect of correcting blindness

Understandably, there are economic benefits resulting from correcting treatable blindness. One study revealed that after children had their cataracts removed, they were granted 50 years of blindness-free life, and as such were better able to contribute to the community (Shamanna, BR. 2004) economically and otherwise. Similarly, researchers noted a 21.9% reduction in lifetime medical payments following simultaneous bilateral congenital cataract removal in infants (Dave, H. 2010).

It has been previously noted, however, that pediatric cataract surgery is much costlier than the same surgery in adults. Typically, the cost of treating children in India ranges from $122-$475 per eye (Gogate, P. 2010) while for adults this procedure may be as low as $12.37 (Muralikrishnan, R. 2004). And, due to the nature of these surgeries the pediatric patients require more follow-ups and as such consume a greater amount of resources (Gogate, P. 2010). Yet when you take into account the overall reduction in blind person-years, it is evident that the pediatric surgery is certainly more cost effective overall for the country's economy (Rahi, JS. 1999).

Other studies revealed an increased number of productive working years when instances of treatable blindness are corrected. Cases of blindness due to uncorrected refractive error cause 30 years of blindness, while blindness due to cataract caused 5 years, which are entirely avoidable years of cost both to individuals and to society. In fact, uncorrected refractive error is cited as the most common cause of visual impairment, accounting for 14.9% of blindness in India (Dandona, L. 2006). This imposes a disproportionate burden on the more productive, younger years of individuals' lives and accordingly has an adverse socioeconomic impact (Dandona, L. 2006).

This observation is not consistent across the whole of the country. In the state of Andhra Pradesh alone, it is reported that 80% of blindness is treatable, thus posing unnecessary social and economic burdens on both inhabitants and societal structure (Dandona, L. 2001).

Demographics and the economic burden

It is well established that age, sex, residence, literacy, and working status are all associated with blindness, with the highest risk for women, those aged 70 and over, as well as for the illiterate (Murthy, GV. 2005) These blind individuals have more limited opportunities to earn an income, further limiting their life choices; they have different experiences with barriers faced, expenditures and health outcomes. (Murthy, GV. 2005; Frick, ND. 2012) For members of society that already face certain barriers or even ostracism, as is the case with the HIV-positive community, the impact of blindness on their household economics can be even more devastating (Murthy, G. 2008). One such study investigated this synergistic effect, and found that screening services for avoidable blindness were less available to HIV-positive individuals due to their social isolation. The impactful costs of ARV also pose serious financial barriers for the blind to be able to afford surgeries that could alleviate their vision-related issues (Murthy, GV. 2008). Overall, blindness in HIV positive persons was found to reduce their economic productivity and increase their economic dependency leading to greater household expenditures – all factors that interact to act disastrously on the socioeconomic makeup of India (Murthy, GV. 2008).

Differing treatment modalities

Problematically, India's ratio of ophthalmologists to population is markedly below the world standard, decreasing individual access to services that could prevent or reverse blindness. Researchers have accordingly called for increased training and hiring of ophthalmologists, and an increase in relevant support staff (Kalam, A. 2007).

The various avenues through which individuals do access ophthalmic services also have differing economic impacts. Non-governmental hospitals are the most cost-effective options for patients, estimated at US$54 per patient. Ophthalmology "camps" that serve primarily rural areas are also a very low cost option. However, with higher rates of adverse outcomes, camps' cost-effectiveness was deemed to be around US$97 per patient. Lastly, the state medical college hospital was cited as the least cost-effective at US$176 per patient (Singh, AJ. 2000).

Differing types of corrective surgeries may further pose variant financial barriers to individuals and their caregivers. Phacoemulsification and manual small incision cataract surgery (MSICS) are sutureless surgeries that impose minimal restrictions on patient's physical activities following the respective procedures. These patients spend very little time in the treatment facility, require minimal follow-up, and may involve themselves in economically productive activities shortly after their surgeries are completed (Muralikrishnan, R. 2004). As a result, these surgeries have average patient costs of US$12.37. Contrastingly, another cataract surgery – extracapsular cataract extraction with intraocular lens implantation (ECCE-IOL) – costs patients approximately US$19.85, due to a longer required length of stay and increased follow-up visits (Muralikrishnan, R. 2004). Additionally, factoring into consideration are the patients' lost daily wages for their surgeries, and the need to pay for food and transportation to the treatment facilities. Economic losses are also similarly incurred by their close relatives/caregivers who need to accompany the patients to their surgeries and follow-up appointments. (Muralikrishnan, R. 2004) One study concluded that, in terms of total societal costs, MSICS is the least costly cataract procedure overall (Muralikrishnan, R. 2004).

Conclusion and Recommendations

It has been well established that blindness poses an immense burden to all those afflicted. However, the extent to which this burden has been (or alternatively, can be) qualified or quantified remains to be determined. From these results we may conclude that at the level of the household, blindness is a heavy economic burden to bear and poses many financial barriers for individual families. What remains unclear are the exact numbers that this burden reflects, based on the limited knowledge available on the current prevalence and incidence of blindness in India. Prevalence and incidence statistics from as far back as 1997 are commonly cited, thus the economic impact figures highlighted in this study do not accurately depict the current situation. More research seeking to measure the current, accurate burden of blindness of India is well advised.

However, based on the 1997 prevalence estimates, it has been suggested that if even 52% of India's cataract blind were treated (at a cost of US$0.15 billion), the savings in the annual GNP would total approximately US$1.1 billion (Shamanna, L. 1998). This is clearly an important issue, in terms of both individual human suffering and national wealth

Chapter Four

The Epidemiology of Ophthalmological Disease Among School Age Children in Rural India

Abstract

Preventable blindness is one of the primary health concerns in rural India, yet little is known about the prevalence of eye disease among India's school-aged children. The clinical database of the Srikiran Institute of Ophthalmology, which describes clinicians' visits to schools in Kakinada, India, was analyzed retrospectively to determine the prevalence of eye disease among 8488 students aged 18 years and younger. Among diagnosed illnesses, basic refractory impingement (including degrees of astigmatism) was the most common, followed by squinting. Vitamin A deficiency was not a factor in any of the tested subjects.

Introduction

The southern Indian state of Andhra Pradesh has an official population of 76.2 million, representing 7% of all Indians who experience slightly lower total and female literacy rates than the national average (Ministry of Health and Family Welfare, 2011). Further, Andhra Pradesh is home to 7% of India's "scheduled" or low caste people (Ministry of Health and Family Welfare, 2011). A study of vision deficit in this area was performed by the LV Prasad Eye Institute in 2001 (Dandona & Dandona, 2001), as part of the World Health Organization's (WHO) VISION 2020 international initiative to contextualize visual impairment as an international public health issue. The WHO estimated that there were 18.7 million blind people in India in 2001, a number projected to grow to 24.1 million by 2010. This is an underestimate in comparison with other studies that suggest that almost 4 million Indians go blind every year as a result of cataracts alone (Singh, Garner, & Floyd, 2000). The comparative depth and rigor of the former study however, suggests that the WHO's VISION 2020 estimate is the more accurate.

Regardless of the disparity in estimates, it is clear that impaired vision is a serious issue in this region. Comprehension and action on this issue are impeded by a general lack of information on the distribution and epidemiology of eye disease in rural India. This is especially true for children, who are rarely the subjects of ophthalmological study. Causes of visual impairment include injury, nutritional deficit, lack of protection against UV rays, and strain due to fine acuity needs. Currently, the extent to which eye disease manifests earlier in life is unknown due to the paucity of investigation in this population.

In the present study, we used a clinical database from an ophthalmological hospital in Kakinada, India, to identify major diagnosable issues experienced by Indian school-aged children. Our intent was to estimate the extent of ophthalmic disease burden in this specific population and to describe and quantify the relationships between disease presentation and demographic characteristics.

Methodology

Clinical and administrative data from the Srikiran Institute of Ophthalmology in Kakinada, India, were obtained for the period from 2003 to 2010. These data describe visits by clinic staff to local public schools, where students (aged 18 years and younger) were screened for basic, diagnosable eye disease. The data also describe the students' treatment regimens and outcomes and refer to a single school visit per child.

Descriptive statistics were employed to determine disease prevalence. Bivariate statistical analyses (chi square and independent samples t-tests) were used to explore relationships between clinical and demographic measures. These tests were deemed appropriate due to the normal distributions (of continuous variables) and large cell sizes (for discrete variables), as well as the dichotomous nature of the outcome diagnosis variable, which was coded as either disease presence or absence.

Permission for this study was granted by the Research Ethics office of the University of Ottawa.

Results

Within the dataset, there were a total of 8488 students 18 years old and younger, of whom 4299 (50.6%) were male and 4189 (49.4%) female. The age of the students was normally distributed (confirmed through examination of measurements of central tendency), with 729 (8.6%) aged from 0 – 6 years, 4920 (58%) aged 7 – 12 years, and the remaining 2839 (33.4%) aged 13 – 18 years.

Upon examination, 4774 (56.2%) students were found to have no diagnosed eye disease. Among the 43.8% with a positive diagnosis, the most common issues were refraction errors (2927; 34.5%), squinting (239; 2.8%), and swelling (108; 1.3%). There were 128 (1.5%) subjects who received multiple diagnoses.

Gender was shown to have a statistically significant association ($p<0.05$) with the development of multiple diagnoses, including: strabismus, redness, itching, microcornea, watering eyes, and an injury obtained to the eye. Among males, there was an increased association of redness ($p<0.001$), itchiness ($p=0.014$), watering ($p=0.031$), and eye injury ($p=0.014$). Females had a higher likelihood of developing strabismus ($p=0.001$) and microcornea ($p=0.042$). The full list of gender associations is presented in Table 1.

Table 1: Association between Gender and Ophthalmological Diagnosis.

Disease	P-value (chi-square)
Strabismus	0.001
Bitot's Spots	0.275
Redness	<0.001
Blepharitis	0.355
Coloboma	0.113
Corneal opacity	0.975
Ptosis (drooping)	0.744
Itching	0.014
Swelling	0.405
Microcornea	0.047
Refraction error	0.304
Squinting	0.994
Watering	0.031
Injury	0.014
Nystagmus	0.318
Cataract	0.964

There was a relationship between the age of students and the diagnosis of strabismus, blepharitis, coloboma, corneal opacity, ptosis, swelling, microcornea, refraction errors, watering, and cataract development. The average age of diagnosis was younger for students with strabismus ($p<0.001$), blepharitis ($p=0.010$), coloboma ($p<0.001$), corneal opacity ($p=0.038$), ptosis ($p=0.001$), swelling ($p=0.026$), microcornea ($p=0.030$), watering ($p=0.016$), and cataract development ($p=0.003$). The only diagnosis that was more likely among older students was refraction errors ($p<0.001$). Associations between diagnoses and age are summarized in Table 2.

Table 2: Association between Age and Ophthalmological Diagnosis.

Disease	P-value (t-test)
Strabismus	<0.001
Bitot's Spots	0.238
Redness	0.972
Blepharitis	0.010
Coloboma	<0.001
Corneal opacity	0.038
Ptosis (drooping)	0.001
Itching	0.104
Swelling	0.026
Microcornea	0.030
Refraction error	<0.001
Squinting	0.601
Watering	0.016
Injury	0.526
Nystagmus	0.774
Cataract	0.003

Unsurprisingly, student grade was associated with most of the same diseases that were found to be associated with age, as both age and grade are highly correlated in this dataset. None of the examined subjects showed signs of Vitamin A deficiency.

Discussion

In rural India, preventable blindness is prevalent at epidemic levels (Singh et al., 2000). The most comprehensive study to date of the Indian population, conducted in 2001, sampled fewer than 12,000 subjects and did not examine children under 15 (Dandona & Dandona, 2001). Nevertheless, they found that the most common causes of impaired vision were retinal diseases (35.2%), amblyopia (25.7%), optic atrophy (14.3%), glaucoma (11.4%), and corneal diseases (8.6%). Not surprisingly, prevalence of reduced vision increased with advancing age and with decreased socioeconomic status (Dandona & Dandona, 2001).

In addition, Dandona and Dandona (2001) found that while cataracts were the leading cause of blindness in the general population, the odds of this statistical association was 96% higher for women than men and (the same association was 72% higher in rural areas). For all causes, women were 37% more likely than men to be blind. It should be noted that the dataset used by Dandona and Dandona was largely comprised of adults. In our sample, while gender differences were present, there was nothing resembling this profoundly disproportionate representation described in the 2001 study. While cataract development was relatively rare amongst children in our study, there was no significant difference in prevalence between males and females.

Furthermore, refraction errors (astigmatism) were the most common diagnoses, followed by various degrees of squinting and then swelling. This result aligns with other global studies of pediatric ophthalmology, including a Swedish study in which astigmatism and strabismus were the most commonly described results after screening (Kvarnström, Jakobsson, & Lennerstrand, 2001). Strabismus was also commonly found in a study pertaining to children adopted from Eastern Europe (Grönlund et al., 2010). For our sample, strabismus was generalized to incorporate various related diagnoses, including alternating exotropia, alternating esotropia, hypotropia, hypertropia, and amblyopia.

Studies examining eye disease among rural Indian school-age children are rare, despite some consensus that global rates of ophthalmological issues among children are rising (Gwiazda, Grice, Held, McLellan, & Thorn, 2000). Diagnosis is a necessary step before treatment. Thus, an inability to detect eye disease at an early age (many of which are likely preventable or curable) hobbles treatment efforts. In reference to the current study, the diagnosis of astigmatism can be corrected with appropriate corrective lenses if the resources are available to the population and a diagnosis can be made. In total, 43.8% of the Srikiran pediatric population was diagnosed with eye disease, which is a concerning number. Beyond age and gender, our study offers no insight into additional factors that may predict the development of eye disease, such as caste, socioeconomic status, nutritional profile, sun exposure, or specific activities pursued. We have demonstrated a high burden of disease among this youth population, which must be the foundation of future investigation into predictive factors and the effectiveness of treatment regimens.

Chapter Five

Determinants of Ophthalmological Health in Rural India: An Analysis of Administrative and Clinical Data

Abstract

Background: The leading cause of blindness worldwide is cataracts, with low and middle income countries such as India being disproportionately affected. With the prevalence of blindness expected to reach 76 million by 2020, approximately 3 million cataract surgeries are performed each year in India. However, individuals still face a variety of factors that mediate cataract development and present barriers to appropriate surgical care and recovery. Research thus far historically been unable to determine some of these factors as a result of insufficient data. With this study, we analyzed a very large ophthalmological database to identify factors associated with both cataract diagnosis and surgery outcome **Methods**: Administrative and clinical data were obtained from the Srikiran Institute of Ophthalmology in Andhra Pradesh, India. In Phase I, we identified the factors associated with cataract diagnosis sufficiently advanced to warrant cataract surgery. In Phase II, determinants of good surgical outcomes, as defined by the absence of post-operative complications, were similarly identified. Statistical tests (chi-square and t-tests for bivariate statistical analysis, and binomial logistic regressions for multivariate analysis) were carried out using SPSS (Version 22). **Results**: In agreement with the literature, advancing age and being female were both associated with cataract diagnosis, as were occupation (agricultural workers being most at risk), ability to pay for services, being of a lower caste (reflecting socioeconomic status), and district of residence. In terms of surgical outcome, age and gender surprisingly were not related to good surgical outcomes. Occupation, and whether individuals could pay for services were still statistically significant, thereby highlighting the role of socioeconomic status in surgical outcomes. **Conclusions**: A variety of factors interplay to affect both cataract development as well as patient outcomes following surgical intervention. Largely individuals of lower socioeconomic status are more likely to be diagnosed with cataract, while being of a lower caste and unable to pay for surgery were significantly associated with poor surgical outcomes.

Introduction

Worldwide, the leading cause of blindness is cataracts – the irreversible opacification of the ocular lens as a result of lens protein degeneration – which is especially true in low-income countries (Resnikoff, S. 2002; Riaz, Y. 2009). The main risk factors for cataract development appear to be increased age, lower social class and educational attainment, occupational exposure to sunlight, and being female (Nanayakkara, S.D. 2009). Blindness and visual impairment substantially impact quality of life, and affect the socioeconomic development of individuals and society at large. This is of particular import when we consider that the global prevalence of blind persons will likely reach approximately 76 million individuals by 2020 (Frick, K.D. 2003).

Low and middle income countries, like India, are particularly vulnerable to the threat of visual impairment, particularly among their poorest residents (Resnikoff, S. 2004). To address this epidemic, approximately 10 million cataract surgeries are performed each year, with 3 million of these carried out in India alone (Foster, A. 2001; Gupta, AK 1998). However, significant barriers to receiving appropriate and effective treatment exist for many individuals, particularly those dwelling in rural locales (Fletcher, A. 1999; Snelligen, T. 1998; Vaidyanathan, K. 1999). Resultantly, there exists a need to investigate further risk factors for cataract development and how this may impact quality of life.

Though select studies have researched such impacts as gender inequity with respect to blindness, they have not investigated a greater range of demographic and clinical variables, or have not simultaneously analyzed multiple factors (Ulldemolins, A. 2012). Furthermore, few studies have been able to successfully link select demographic and clinical factors with adverse outcomes as the majority of studies focused more narrowly on one pathology or treatment (Marmamula, S. 2013; Bell, C. 2007; Hatch, W. 2009; Bjerrum, S. 2013). Gleaning such an improved understanding will be important in the future, as the rates of cataract surgery will likely need to increase in order to address the rise in incidence of cataract blind persons, and to assist in serving the existing backlog of patients currently requiring such procedures (Venkatesh, R. 2005). An examination into cataract surgical services is currently necessary in order to better identify those factors which lead individuals to require such procedures, as well as to achieve an ameliorated view of how patient outcomes are affected by diverse demographic and clinical factors (Foster, A. 1999; Venkatesh, R. 2005).

Over half the cases of worldwide blindness occur in India. Treatment success rates in India are less than ideal, thus necessitating deeper research into service improvement (Dandona, L. 2001; Lindfield, R. 2008; WHO 1998). Accordingly, this study aims to investigate which variables –demographic, behavioural, and clinical- are associated with surgical need (i.e. whether examined patients require cataract surgery), and which factors are associated with good treatment outcomes in a special rural Indian population.

Methodology

Population

This study involves the analysis of existing hospital data collected by the Srikiran Institute of Ophthalmology, a facility primarily servicing needful individuals in the Indian state of Andhra Pradesh. These data were both administrative and clinical in nature. The data were collected by hospital staff from 1993 to 2010, from patients seeking ophthalmic treatment from the institute's base hospital. For the purposes of this research, patient encounters were selected on the basis of the comprehensiveness of their files; that is, records were extracted if they included information related to their demographics as well as related to their surgical need, or surgical outcome. This resulted in a population of 25,620 patient encounters that remained in the study. We believe that these data represent the largest clinical database of ophthalmological patients to have ever been investigated epidemiologically.

Organization of the data

The data were collected and stored initially for administrative, and not research, purposes, and stored in Microsoft Access Database format. Database linkages were performed to associate patient encounters with their relevant demographic and clinical content (such as age, gender, caste, and outcome of visit). The relational databases were then converted to a single "flat file" in Microsoft Excel format. Data cleaning was performed to eliminate duplicate entries and suspected typographical errors. Furthermore, categories under select demographics were created in instances where the subpopulation was too minute to appropriately analyze. For example, there were over thirty separate occupations listed yet over 95% of the patient population accounted for only six of these and thus the others were grouped under the heading of “other”. Similar processes were repeated for other descriptors as necessary. The file was then converted to SPSS format for statistical analysis.

Data Analysis

Bivariate statistical analyses (in the form of chi square and independent samples t-tests) were carried out in SPSS (version 22) to determine whether unadjusted relationships existed between select demographic variables (as outlined in Table 1) and patient outcomes. Based on these results, demographic and clinical factors were selected for further study. In order to be included in further analyses, a particular variable was required to have a significant independent association with the outcome of interest (cataract diagnosis or poor surgical outcome) at the level of $p<0.05$. Initial variable are summarized in Table 1.

Table 1: Variables Used in Chi-Square, T-tests, and Logistic Regression

Variable	Data Type
Gender	Nominal
Age	Continuous
Caste	Nominal
Occupation	Nominal
District	Nominal
Payment Status	Nominal
Surgery Type[1]	Nominal
Eye requiring treatment	Nominal
Intraocular Lens (IOL) Power[2]	Nominal
Intraocular Lens (IOL) Material	Nominal

For the purposes of this analysis, patient encounter outcomes were defined in two ways: firstly, factors were identified for patients that required surgical follow-up versus those patients who did not; and secondly, poor surgical patient outcomes were defined as those patients with clinical complications post-operatively versus those who did not. These definitions are more clearly highlighted in Table 2. Because the vast majority of patients requiring surgery are those suffering from cataract blindness, this first definition allows us to approximate the factors that influence patients developing preventable blindness. Accompanying this exploration with the second definition may

[1] In the analyses, "surgery type" consists of three main procedures: extracapsular cataract extraction with intraocular lens implantation (ECCE-IOL), manual phacoemulsification with IOL implantation (PHACO), and combined surgeries (for cataract removal). ECCE-IOL is reported to be one of the more common surgeries in India based on its success and ease of use (Muralikirshnan, R. 2004; Gupta, AK 1998; Natchia,, G. 2000; Venkatesh,, P. 1998). However, PHACO seems to be more widely used in the developed world: because it does not require the use of sutures, it lessens recovery times and leads to more successful patient outcomes (Dada, VK. 1999). It is not as widely used in India based on its need for increased training time and equipment maintenance, though its popularity is on the rise (Natchia, G. 2000; Venkatesh, P. 1998). Also included under this category are "other" cataract surgeries that numbered too few individually to be significant and thus were combined into one category.

[2] IOL Power refers to the refractive strength of the lens, and is commonly determined by calculations involving axial length, corneal power, and the position of the IOL within the eye (Ghanem, A. 2005; Holladay, J. 1985).

offer a better understanding of those variables that influence better patient prognoses following corrective surgery.

Table 2: Definitions of patient outcome

Type of analysis	Good patient outcome	Poor patient outcome
Factors affecting need for surgical intervention (for preventable blindness)	Non-surgical treatment	Surgical treatment
Factors affecting surgical outcome	No post-operative complications	Presence of post-operative complications

With the establishment of any pre-existing relationships between demographic variables and patient outcomes, and applying these above definitions of patient encounter outcome, a binary logistic regression followed using SPSS with "good patient outcome" used as the baseline outcome. Accordingly, the extent to which the diverse factors contribute to patient outcome was elucidated.

Research Ethics

The Research Ethics office of the University of Ottawa granted permission for this study.

Results Part I: Assessing Factors in Relation to Surgical Need

Characteristics of the Population

The number of patient encounters totaled 25,620. Of these, 61.2% (15,671) were non-surgical in nature (i.e. had a "good" outcome not requiring surgery) and the remaining 38.8% (9,949) required surgical intervention. A slight majority of the encounters were by female patients at 52.1% (13,358) while 47.9% (12,262) were male. Further descriptors of the population analyzed are highlighted in Table 3.

Table 3: Population characteristics for surgical and non-surgical patient encounters

Variable		Number	Distribution Percentage
Caste	Scheduled Castes	4,722	18.4
	Scheduled Tribes	477	1.9
	Brahmin	12,382	48.3
	Other backward classes	274	1.1
	Other castes	7765	30.3
Occupation	Agriculture	1,172	4.6
	Dependent	4,950	19.3
	General Labourer	8.138	31.8
	Housewife	4,177	16.3
	Student	1,786	7.0
	Coolie (unskilled labourer)	4,324	16.9
	Other	1,073	4.2
District	East Godavari	23,026	89.9
	Khammam	1,058	4.1
	Visakhapatnam	498	1.9
	West Godavari	551	2.2

	Other	487	1.9
Payment	Non-Paid	25,095	98.0
	Paid	525	2.0

Determining Covariates for the Regression Analysis

The vast majority (that is, greater than 97%) of those patients requiring surgical attention are related to preventable blindness in the form of cataract removal. Accordingly, in assessing the factors that differentiate between those patient encounters requiring surgical intervention versus those that do not, we are in fact studying variables mediating instances of preventable blindness.

To this end, six (6) variables were available to compare across the two outcome groups, namely surgical versus non-surgical patients. Chi square tests were performed on the nominal variables to assess any existing relationships; this process was repeated for age via the independent samples t-test as highlighted in Table 4. All factors showed significant association with a need for surgery, thus all were introduced into the logistic regression model.

Table 4: Unadjusted relationships between the selected covariates and whether the patient encounter required surgery

Demographic Variable	**P-value**
Female (compared to male)	<<0.01
Caste	<<0.01
Occupation	<<0.01
District	<<0.01
Payment (Paid or Non-Paid)	<0.01
Age	<<0.01

Binomial Logistic Regression Analysis for Surgical Need

The data for the variables as previously described were entered into SPSS and the logistic regression was carried out for a total of 25,620 patient encounters. Those instances in which surgical interventions were not required were used as the reference category. The outcome of interest is "surgical need", which is a proxy measure for diagnosis of severe cataract. More precisely, it is a measurement of cataract serious enough to warrant recommendation for surgery. The results of this analysis are displayed in Table 5.

Table 5: Adjusted odds ratios of factors associated with a need for cataract surgery (results of logistic regression)

Variable		Odds Ratio	95% Confidence Interval	
			Lower Bound	Upper Bound
Age		1.060	1.057	1.063
Female compared to male		1.285	1.206	1.370
Payment	Non-Paid	0.128	0.102	0.160
	Paid	Reference variable		
Caste	Scheduled Castes	1.094	1.005	1.191
	Scheduled Tribes	1.135	0.903	1.425
	Brahmin	1.048	0.981	1.119
	Other backward classes	0.777	0.595	1.013
	Other castes	Reference variable		

Occupation	Agriculture	1.084	0.932	1.261
	Dependent	0.300	0.273	0.330
	General Labourer	0.332	0.306	0.362
	Housewife	0.563	0.508	0.624
	Student	0.560	0.451	0.696
	Other	0.484	0.415	0.565
	Coolie (unskilled labourer)	Reference variable		
District	East Godavari	0.455	0.375	0.552
	Khammam	2.069	1.590	2.691
	Visakhapatnam	0.359	0.271	0.475
	Others	0.439	0.333	0.579
	West Godavari	Reference variable		

From Table 5, the factors statistically associated with surgical need were: being female, belonging to a scheduled caste, an inability to pay out of pocket for surgical care, and living in Khammam region. Of the occupations explored, there were none positively associated with surgical need; rather, dependents, general labourers, housewives, students, and other occupations were significantly associated with the non-surgical outcome. To further clarify the results of the logistic regression, we may compare the differences between the unadjusted and adjusted p-values, as highlighted in Table 6. .

Table 6: Comparison between unadjusted and adjusted p-values for surgical need covariates. Changes in significance are bolded.

Variable		**Unadjusted P-Value**	**Adjusted P-value**
Age		<<0.01	<<0.01
Female (compared to male)		<<0.01	<<0.01
Payment	Non-Paid	<<0.01	<<0.01
	Paid	Reference variable	
Caste	Scheduled Castes	<<0.01	0.038
	Scheduled Tribes	<<0.01	0.278
	Brahmin	0.289	0.167
	Other backward classes	0.049	0.063
	Other	Reference variable	
Occupation	**Agriculture**	<<0.01	0.294
	Dependent	<<0.01	<<0.01
	General Labourer	<<0.01	<<0.01
	Housewife	<<0.01	<<0.01
	Other	<<0.01	<<0.01
	Student	<<0.01	<<0.01
	Coolie (unskilled labourer)	Reference variable	
District	East Godavari	<<0.01	<<0.01
	Khammam	<<0.01	<<0.01
	Other	<<0.01	<<0.01
	Visakhapatnam	<<0.01	<<0.01
	West Godavari	Reference variable	

A key finding is that the significance of belonging to a scheduled tribe only becomes evident when other factors are controlled by the regression process. Contrastingly, the importance of being an agricultural labourer or belonging to “other backward classes” diminishes in the regression model.

Results Part II: Assessing Factors in Relation to Surgical Outcome

Characteristics of the population

Patient characteristics on the whole were explored. Due to a smaller number of patient encounters that had complete data, for this analysis only 8,875 patient encounters were examined, of which 93.5% (8,297) were deemed to be "good" and 6.5% (578) were poor (as previously described in Table 2). 55.4% (4,920) of the encounters were by female patients while 45.6% (3955) were by males. Further characteristics are elaborated below.

Table 7: Population characteristics for surgical patient outcomes

Variable		Number	Distribution Percentage
District	East Godavari	7,458	84
	Khammam	830	9.4
	Visakhapatnam	136	1.5
	West Godavari	286	3.2
	Other	165	1.9
Occupation	Agriculture	718	8.1
	Dependent	1,910	21.5
	General Labourer	1,908	21.5
	Housewife	1,650	18.6
	Coolie (unskilled labourer)	2,279	25.7
	Other	410	4.6
Surgery Type	Manual Phaco + IOL	8,411	94.8
	ECCE + IOL	210	2.4
	Combined Surgery	163	1.8

	Other	91	1.0
Payment	Non-Paid	8,531	96.1
	Paid	344	3.9
Eye Requiring Treatment	Oculus sinister (left)	4,663	52.5
	Oculus dexter (right)	4,212	47.5

Determining covariates for the regression analysis

Bivariate analyses were performed to determine the unadjusted association between key predictive variables and whether a surgical outcome was good or poor. Chi-square analyses were applied to the nominal variables as above, with ten (10) variables under investigation; similarly, the sole continuous variable, age, was tested via the independent samples t-test. Results are summarized in Table 8.

Table 8: Unadjusted relationships between selected covariates and whether patients had poor surgical outcomes. Statistically significant associations are labeled with an asterisk.

Demographic Variable	P-value
Female (compared to male)	0.757
Caste	0.469
Occupation	**<<0.01**
District	**0.013**
Payment	**0.020**
Surgery Type	**<<0.01**
Eye (Oculus sinister vs. oculus dexter)	0.090
IOL Power	**0.048**
IOL Material	0.708
Age	0.913

Factors showing an association at the $p<0.10$ were entered into the subsequent logistic regression model.

Binomial Logistic Regression Analysis for Surgical Outcome

The results of the logistic regression analysis showing which covariates are associated with a poor surgical outcome are summarized in Table 9.

Table 9: Adjusted odds ratios of factors associated with poor surgical outcomes (results of logistic regression)

Variable		**Odds Ratio**	**95% Confidence Interval**	
			Lower Bound	**Upper Bound**
Age		1.001	0.993	1.009
Female (compared to male)		1.004	0.827	1.221
Payment	**Non-Paid**	**2.106**	**1.158**	**3.827**
	Paid	Reference variable		
Occupation	Agriculture	0.638	0.400	1.017
	Dependent	**1.653**	**1.274**	**2.144**
	General Labourer	**1.475**	**1.140**	**1.909**
	Housewife	1.107	0.815	1.503
	Other	1.132	0.704	1.818
	Coolie (unskilled labourer)	Reference variable		
District	East Godavari	1.163	0.680	1.991
	Khammam	0.879	0.464	1.666
	Visakhapatnam	1.134	0.507	2.538
	Others	1.695	0.778	3.692
	West Godavari	Reference variable		
Eye	OD	0.873	0.735	1.038
	OS	Reference variable		
Surgery	Manual Phaco + IOL	**0.946**	**0.085**	**0.216**
	ECCE + IOL	**0.159**	**0.077**	**0.326**
	Combined Surgeries	0.136	0.537	1.665
	Other	Reference variable		
IOL Power	19	0.916	0.507	1.656

	19.5	0.567	0.307	1.044
	20	0.819	0.520	1.290
	20.5	0.726	0.471	1.119
	21	**0.637**	**0.421**	**0.963**
	21.5	0.802	0.553	1.163
	22	**0.645**	**0.441**	**0.942**
	22.5	1.018	0.715	1.451
	23	**0.647**	**0.431**	**0.971**
	23.5	0.714	0.470	1.086
	24	0.855	0.566	1.292
	25	0.809	0.475	1.379
	Other	Reference variable		
Caste	Scheduled Castes	1.232	0.963	1.576
	Scheduled Tribes	1.116	0.594	2.098
	Brahmin	0.972	0.791	1.196
	Other Backward Classes	0.951	0.423	2.137
	Other	Reference variable		

Among patients who underwent cataract surgery, the most prominent factor associated with a poor outcome was not being able to pay out of pocket. Relative to being a coolie, being a dependent or general labourer was associated with a poor surgical outcome.

In Table 10, the unadjusted and adjusted p-values are presented for comparison.

Table 10: Comparison between unadjusted and adjusted p-values for poor surgical outcome. Changes in significance at the p<0.05 level are bolded.

Variable		Unadjusted P-value	Adjusted P-value
Age		0.757	0.867
Female (compared to male)		0.912	0.964
Non-paid		0.023	0.015
Caste	Scheduled Castes	0.171	0.098
	Scheduled Tribes	0.817	0.734
	Brahmin	0.715	0.790
	Other backwards classes	0.963	0.903
	Other		
Occupation	**Agriculture**	**0.034**	**0.059**
	Dependent	<<0.01	<<0.01
	General Labourer	<<0.01	0.003
	Housewife	0.542	0.517
	Other	0.690	0.609
	Coolie (unskilled labourer)		
District	East Godavari	0.321	0.582
	Khammam	0.415	0.693
	Other	0.384	0.759
	Visakhapatnam	0.060	0.184
	West Godavari		
Surgery Type	Combined surgery	0.996	0.847
	ECCE + IOL	<<0.01	<<0.01
	Manual Phaco + IOL	<<0.01	<<0.01
	Other		
Eye Treated	OD	0.090	0.124
	OS		
IOL Power	19	0.545	0.772

	19.5	**0.027**	**0.069**
	20	0.230	0.388
	20.5	**0.047**	**0.147**
	21	0.005	0.032
	21.5	0.033	0.245
	22	0.002	0.023
	22.5	0.458	0.920
	23	0.007	0.036
	23.5	**0.021**	**0.116**
	24	0.147	0.457
	25	0.470	0.437

Discussion

Key Findings

Cataracts are the leading cause of blindness in the world, which is particularly true in low-income countries (Riaz, Y., 2009). In India, though many cataract operations are performed each year (with 3.5 million procedures carried out in 2000), there still remains an appreciable gap between individuals needing surgical intervention and those receiving it; further complicating the situation are poor patient outcomes and barriers to treatment access (Venkatesh, R. 2005). Of the population requiring surgical intervention in this research, over 97% was for cataract removal. In the first set of analyses, therefore, the need for surgery (which was defined as “poor” patient outcome) may be used as a proxy for incidence of cataracts. Thus, those factors herein that play a role in surgical need may also be predictive, on a larger, more generalizable scale, of preventable blindness. Previous investigators have also highlighted the need toward increased understanding in what factors contribute to poor outcomes in avoidable blindness procedures (Dandona, L. 2001). Many studies undertaken have had insufficient power to delineate trends in the data, and thus it has been historically difficult to link various demographic factors and clinical variables with adverse surgical outcomes (Bell, C. 2007; Hatch, W. 2009; Bjerrum, S. 2013; Al-Shakarchi, F. 2011). The aim of this research, resultantly, was to identify factors implicated in both surgical need (i.e. cataract removal) as well as in poor surgical outcomes.

From the statistical models exploring outcome as defined by surgical need, it is evident that gender is an important factor with females more likely to require surgery than males (OR: 1.285; 95% CI: 1.206-1.370). This is consistent with what has been established in the literature: females have a higher risk of cataract blindness due to inadequate access to initial eye health services, and they are more likely to undergo surgery as a result of increased motivation to use available services (Vivekanand, U. 2005). Also frequently cited in the literature as one of the most important determinants for cataract development (and thus a requirement for surgery) is increased age (Nanayakkara, S.D. 2009); such a result was also evident in this study, in which increased age was positively associated with surgical need (OR: 1.060; 95% CI: 1.057-1.063).

Additionally of especial interest is the positive association between surgical need and belonging to the scheduled castes; patients belonging to this group are among the most disadvantaged individuals in Indian society, both socially as well as economically. Again, this is supported by previous research which revealed that lower socioeconomic status and educational attainment more often lead to the development of cataracts (Khanna, R. 2007). Unsurprisingly, patients' districts of origin also played a role in surgical need: in particular, patients residing in Khammam (a district of Andhra Pradesh) were more likely to exhibit surgical need compared to the other regions (OR: 2.069; 95% CI: 1.590-2.691). This may reflect socioeconomic status as this region showcases a lower district domestic product than other districts in the state, and corresponds with known correlations between rural provenance and cataract development (Reddy, A. 2013; Khanna, R. 2007). Occupation was another important factor in patient encounters requiring surgical intervention. Other than those patients involved in agriculture, each occupation was less likely than the unskilled labourers (coolies) to lead to surgery. And, this may be an indicator of environmental exposures that lead to cataract development: occupational exposure to sunlight and the failure to wear appropriate protective devices, including hats and protective eyewear, certainly play a role in cataract etiology (Nanayakkara, S.D. 2009; Theodoropoulou, S. 2011). Future research into the extent to which these occupations cause increased UV exposure, and the number of individuals engaging in the appropriate preventative measures, will be instrumental to understanding how this effect can be alleviated to better ophthalmic health.

Contrastingly, not having paid is negatively associated with surgical need; that is individuals who have not paid for their encounters are less likely to have surgery (OR: 0.128; 95% CI: 0.102-0.160). Rather than contradicting the other indicators of low socio-economic status, this may simply be an indication that individuals with lower incomes are unable to pay for surgical procedures and their associated costs (e.g. travel, time away from work, etc.) and therefore do not follow up accordingly. Overall, therefore, these findings are largely consistent with those determinants of health as highlighted in the literature, and shed further light onto some of the specific covariates implicated in health outcomes. This interpretation is complicated by the strong probability that the Srikiran Institute often offers free care to those who cannot pay. Follow-up with the hospital regarding the specifics of their policies may shed more light on this finding.

To provide further illumination into factors influencing patient encounters, analyses were also carried out in terms of good versus poor surgical outcomes. In the present study, 6.5% of patient encounters experienced poor surgical outcomes in the form of postoperative complications; research by Vivekanand et al reported an operative complication rate of 3.4% - both figures lower than those observed in similar locales across Asia, who report a range of rates of 8-21% (Vivekanand, U. 2005). Improper training of support staff and deficient management guidelines were cited as the underlying cause, however an overall lack of man-power and infrastructure were thought to be major hurdles to delivering high quality patient care (Vivekanand, U. 2005). Such effects could be contributing factors in the poor surgical outcomes described above.

Surprisingly, neither age nor gender played a role in influencing poor surgical outcome, though both are oft-cited in the literature as playing key roles (Khanna, R. 2013). Similarly, the effect of rural living on poor surgical outcome is also commonly indicated in the literature, however this was also not evident in the study herein (Al-Shakarchi, F. 2011; Ulldemolins, A. 2012). Indeed, other factors such as occupation and whether the patients had paid were instrumental in determining whether the patient encounter was “good” or “poor”. Of the variables investigated, it appears that not having paid and being a dependent were the key factors positively associated with poor patient outcomes. These effects may in fact be rooted in individuals’ underlying socioeconomic statuses: individuals who did not pay for their treatments may in fact be unable to afford to do so, and patients categorized as dependents are not working (and often, elderly) and subsequently not gleaning any earnings. These will evidently impact patient socioeconomic status and potentially explain their poor outcomes, which is highly consistent with other findings in the literature (Al-Shakarchi, F. 2011; Ulldemolins, A. 2012).

The power of the intraocular lens (IOL) used in the cataract removal procedures appears to be the final covariate to be of important in poor surgical outcome. The reasons for this relationship are unclear, and have not been extensively studied in similar research, however it may simply be reflective of patient anatomy (such as corneal power and axial length of the eye). Future studies may better investigate this effect and provide insight into how such an impact can be minimized.

In both analyses, it is evident that the proxy markers of socioeconomic status were important in allowing for good patient outcomes. Though patients may be afforded low-cost options in ophthalmic treatment, the other out-of-pocket expenses to consider, such as travel to the clinic – the distribution of patient districts of residence revealed that many individuals are indeed traveling appreciable distances to receive appropriate treatment – still pose significant barriers to access and prognosis. With the proportion of blind individuals steadily increasing, this will certainly have to be addressed in order to improve on patient outcomes in the future. A better understanding of why some of these factors are involved will also be necessary, e.g. what environmental or behavioral agents are causing more female patients to require (or follow-up with) surgery.

Study Limitations

A number of limitations stem from the fact this is a secondary analysis of the data in question. The administrative and clinical data were not collected for the purposes of research, but instead were part of routine procedures. As such, the data were not clean, and not overly comprehensive, which may impact the analysis. For instance, such features as occupation and caste were used as proxy indicators of socioeconomic status because household incomes were not asked as part of the administrative data collection process.

Furthermore, because of the nature of the data it was impossible to research individual patients, and instead individual patient encounters were used instead. This results from the fact that many patients were treated more than once, undergoing a different procedure during each visit or needing care for a different eye. Thus, separate patient encounters were used instead.

In terms of patient outcomes, these were somewhat arbitrarily defined by whether patients required surgical intervention, and subsequently whether they had postoperative complications. The data did not include more explicit definitions of patient outcomes, and because many patients do not follow-up after their initial encounter this was the most comprehensive means of defining outcome for the purposes of this research. Additionally, the data were housed as separate files in Microsoft Access Database. This means that some patient demographic and clinical information were in different databases, and had to be joined according to patient identification numbers. In order to obtain the most comprehensive dataset to be analyzed, therefore, patient encounters were only included if they had complete information regarding the covariates to be studied. Resultantly, some patient encounters (i.e. those patients missing extensive information, such as whether they required surgery or not) were omitted from the analysis.

Though intraocular lens material had been initially investigated for its effect on whether patients had poor surgical outcome, it was left out of the regression analysis. When the analysis was run in SPSS, IOL Material was kicked out because of the extremely limited number of different material types (that is, the vast majority all used the same material).

Conclusions – Implications for Policy

From a better understanding of the factors that influence patient outcomes (whether in the need for surgery, or postoperatively in the form of complications), new models of patient care may be developed. Such models can address the traditionally important factors that play key roles in good outcomes, including age, gender, socioeconomic status, and district of residence. In this study, select districts were determined to result in higher surgical need, e.g. Khammam, and as such preventative interventions should target these regions in particular. In general, districts with decreased economies and with a rural designation have shown to be implicated in surgical need, and thus increased resources should accordingly be allocated to these areas. Such investments may take the form of improvements to patient health literacy and knowledge concerning cataracts, or in increased eye health services in the form of more ophthalmology clinics. Indeed, with the prevalence of cataract blindness continuously on the rise, an increase in clinics performing corrective surgeries will be critical to improved quality of patient care, and to address the incredible backlog of needful individuals (Venkatesh, R. 2005; Kovaj, V. 2007). Further, because of the role played by occupation in cataract development in these areas, it will be essential to improving patient health to ensure individuals are aware of their UV exposure and how this may influence their ocular health. In terms of patient surgical outcomes, it was clear that patient payment status and occupation were among the greatest contributors to poor postoperative results. And, in effect, this is reflective of lower socioeconomic status. Ensuring these populations have ample resources to achieve better surgical outcomes, such as in finances that counterbalance their out-of-pocket surgical expenses, may contribute to improved patient health.

Chapter Six

General Discussion

Interdisciplinary Perspective

The impact of blindness in India is multifaceted, and its complexity is heightened by the diverse factors that contribute to its etiology. When investigating the need to address issues in health, we commonly turn to the direct impact on quality of life and the reduction in disability-adjusted life years any intervention may have. For blind persons (or avoidably blind, as is the case with cataracts), these effects are clearly widespread as affected individuals require assistance with nearly all activities of daily living. However, underscoring the severity of blindness is its economic impact: a systematic review of the literature has conferred greater understanding of the extent to which blindness is affecting economics, as discussed in Chapter 3. Understandably, blindness will affect individual and household economics: blind persons will be unable to work, and will thus have decreased contributions to household incomes (Finger, R. 2012). Further, as a result of the burden associated with close supervision of and assistance for their dependent family members, caregivers of blind dependents experience increased incidences of depression. This, in turn, will decrease their contributions to mainstream economic activities (Braich, PS. 2012). These economic effects are not isolated at the micro- level, and instead can be felt at the level of the national economy. This is particularly true in India, which houses the majority of the world's blind (Dandona, L. 2001). Estimates from 1997 report the burden of blindness as US$4.4 billion for that year, with cumulative losses over the lifetime of the blind totaling US$77.4 billion (Shamanna, BR. 1998). Surprisingly, the amount attributable to preventable or curable blindness was US$52.5 billion, nearly half of which stems from cataracts alone (Shamanna, BR. 1998). As the prevalence of blindness continues to increase, with figures expected to double by 2020, these effects will be even more harshly felt (Dandona, L. 2001; Venkatesh, R. 2005; Jose, R. 1997; Frick, K.D. 2003). Accordingly, to alleviate the burden the blind experience, a better understanding of the determinants of ophthalmological health is necessary; such an understanding will set the groundwork for programs and policies that reduce the impact of blindness.

Historically, nutritional deficit has been cited as a major contributor to visual impairment (Akhtar, S. 2013). Also associated with blindness are such factors as age, sex, residence, literacy, and working status (Murthy, G.V. 2005). Some of these factors that play into any of the outcomes investigated are hard to tackle without first investigating them further. For instance, some of the occupational effects may actually stem from behaviors, and so these avenues have to be explored in other research undertakings. This is also true for the effects seen because of belonging to select castes, which are thoroughly ingrained in the Indian societal structure. The inequalities faced by these groups has been criticized in social research, and the government officially recognizes the discrimination faced by some of these groups, however it is difficult to ascertain the extent to which this stratification may change, and how this will influence health outcomes. More research in this area would certainly help further the cause of these castes' peoples.

Blindness is commonly studied in older populations – one of the most comprehensive studies excluded children under 15 – while adolescent populations have largely been ignored. To this end, in Chapter 4 an analysis of factors that contribute to ophthalmological issues in youth was carried out to address this knowledge gap. Attaining a better understanding will not only influence policy to target those key variables at play, but also by preventing blindness at younger ages the economic gains are significantly more substantial (Rahi, JS. 1999). Unfortunately, there were limited demographic information available for this population, including caste, district of origin, payment ability, etc. As revealed by the results of Article III, these data were especially relevant in disease presentation, and accordingly future research should be undertaken to elucidate any role these factors are having. Of the variables studied in their relation to ophthalmological issues in youth, vitamin A deficiency was surprisingly not evident in any of the subjects examined, including those affected by ocular illness. In the future, it may still be beneficial to study the role of vitamin A deficiency in ophthalmological disease presentation in the general adult population as well, for these data were not available in the current investigation. Among the most common diagnoses in this population studied were refraction errors and swelling, both of which were determined to be associated with increased age (Velkers, C. 2014). Also commonly occurring was squinting, however unlike the other diagnoses it was not associated with age or gender. Interestingly, cataract development was associated with younger age in the population studied. If left untreated, these issues are likely to worsen, increasing the incidences of blindness in this population and contributing to the burden experienced not only by individual persons but also the country as a whole.

Bearing such results in mind, a more in-depth investigation of a rural Indian population was undertaken in Chapter 5. This study looked more specifically at the determinants of cataract development (and accordingly the need for cataract removal), as well as the factors that contribute to good surgical outcomes (void of post-operative complications). Such an investigation is paramount to addressing the effects of blindness in India, as cataracts are the major contributors. The results of this study, which investigated over 25,000 patient encounters, were enlightening. Significantly associated with surgical need were: being female, belonging to a scheduled caste (and accordingly being of lower socioeconomic status), not being able to pay out of pocket for surgical care, and living in the region of Khammam (which displays lower district domestic product than other districts in the state of Andhra Pradesh). Overall, therefore, low socioeconomic status is arguably the most important factor in the etiology of cataract blindness and the need for cataract surgery. This highlights the importance of providing affordable (or cost-free) services that are accessible to rural residents, and particularly increasing the use of such services by females. When we look at determinants of good surgical outcome, the requirement for such affordable services is even further elucidated: the most prominent factor associated with a poor surgical outcome was not being able to pay out of pocket. Being a dependent or general labourer, relative to being a coolie (unskilled labourer), was also associated with poor outcome and may again reflect low socioeconomic status. It is important to note here that other costs are associated with undergoing cataract removal: it is not a simple matter of the surgery being affordable, but also having other services to support needful individuals. For instance, these individuals also need to pay for travel to the service center, accommodations while they are there, food, and all the additional costs associated with having a caregiver accompany the dependent individual to their treatment. Further, certain procedures have been shown to be more cost-effective not only in the materials and training required for the procedure, but also in the lower recovery times experienced by patients that allow them to return to work earlier. Investing in such procedures, notably manual small-incision cataract surgery (MSICS), will be of greater benefit towards alleviating blindness and encouraging economic participation (Agarwal, A. 2011).

From the results of the epidemiological investigations, we see a high proportion of individuals suffering from ophthalmological disease. In the case of the school-aged children, public school screenings revealed 43.8% of individuals presenting with eye disease (compared to the estimated global prevalence of 20% of children impacted thusly). Further, 38.8% of the base hospital population had cataracts severe enough to warrant surgical intervention. Bearing in mind that approximately 17% of the global population is impacted by cataracts, and the fact that cataracts represent 51% of causes of blindness, these are indeed alarming figures that require intervention. Evidently, the public school outreach program was an effective means by which eye disease was detected, allowing for early intervention and treatment. This is especially true for those children diagnosed with cataract who, counter-intuitively, were majorly in the younger population. In continuing with such outreach programs, we may alleviate some of the cases of preventable blindness. Further, in incorporating education surrounding eye disease prevention into these outreach efforts, we may further prevent some of this disproportionate prevalence of ophthalmological disease. Such efforts may include information on UV exposure, and the distribution of sunglasses as has previously been carried out in other countries with great success (Theodoropoulou, S. 2011). With continued early screenings, there will be fewer years of life lost to blindness, and increased participation in economic activities in the future. However, not everyone who presents with ophthalmological disease proceeds with treatment, and not everyone that undergoes treatment has a successful outcome. Financial barriers certainly play a role, however future research should further explore whether eliminating all treatment costs impacts patient outcomes, and what other variables may be relevant (including behavioral items such as time spent in the sun, physical activity, and others).

Additionally, the results of the epidemiological investigations revealed the roles played by gender and age. Notably, these variables were responsible for a number of differences in disease presentation in the school-aged population, for instance with younger children being more affected by cataracts. Age and gender were also important in the adult population in terms of cataract development, but not in terms of good surgical outcomes. Both pediatric and cataract patients are economically (and otherwise) dependent on others. They will have fewer opportunities to access treatment and have greater need for supports and resources. Rural populations are historically more affected as well (which was also revealed in the course of this research) and yet are typically underserviced. And, individuals in these groups, if left untreated, will suffer future barriers to earning income, and subsequently greater economic hardship. Therefore, work needs to be done to ensure greater availability of ophthalmological screening and treatment efforts, and should ease the access to such services, particularly for the aforementioned groups. Whether this is in the establishment of more ophthalmology treatment centers, particularly in districts and states with higher proportions of affected individuals, or in increasing transportation services to such centers is unknown. Future research could investigate the impact of various interventions and accessibility on use of services, and how these interventions could be improved. It must be noted that barriers to accessing ophthalmological services and treatment are not dependent on the absolute costs alone, but rather extend beyond into other domains. Even with subsidized costs for treatment options, costs remain for transportation, food, accommodations, lost wages of attenders, etc., and certain groups will be more adversely impacted than others. More resources need to be provided for these auxiliary costs as well in order to maximize the proportion of people who can receive treatment. Such investments will save healthcare costs in the long-run, and will ensure a population contributing to mainstream economic activities beyond the impact on individual qualities of life.

When we consider both the economic and epidemiological aspects of the issue of blindness in India, it is clear that action needs to be taken. With such a severe impact on the country's GDP, as well as on the level of individual household finances, health interventions are paramount to alleviating the situation. With district of residence and occupation acting as key determinants in ophthalmic health outcomes, focusing preventative efforts in these spheres may be of most benefit. Notably, if occupational or geographic exposures to UV are problematic, then increased education and promotion around preventing the ill effects of UV will be incredibly beneficial in preventing cataract development and the requirement for surgery. Such a program was issued in Greece with dramatic results (Theodoropoulou, S. 2011). Furthermore, if socioeconomic status is coming into effect for either "good" health outcome (i.e. not developing cataracts, or alternatively not having post-operative complications following cataract removal) then steps need to be taken to address this as well. For instance, accessibility of services may in fact be a key issue at play: those individuals unable to pay for services may also be unable to pay for transportation, or have a family member accompany them to their appointments (which would logically lead to said individuals missing work and thus losing income). In addition, individuals that are remotely located may also have deficient access to services, and may delay earlier ophthalmological consultation or treatment because of this. Consequently, these individuals may face worsened pathologies (development of cataracts) or prognoses (post-operative complications). Increasing the number of government-funded ophthalmology centers, or alternatively increasing subsidies available for travel to and from the existing services, may work towards improving ophthalmological health and health outcomes. Also of import is the availability of health care professionals who may treat the population, most notably ophthalmologists. The literature indicates there is a disproportionately low ratio of ophthalmologists to both support staff and to the general population, which certainly impacts service accessibility. Efforts in recruitment and retention of such individuals in needful districts will be paramount to addressing the backlog of patients and the exponentially increasing prevalence. And, investments will need to be made to incentivize the pursuit of these careers, including provisions for education and training.

In order to establish effective programs and policies that will address some of this burden, further research needs to be enacted that can elucidate how these factors are impacting patient care. Subsequently, new models of care can be developed, implemented and financed by various levels of government and non-governmental organizations. Such investments will be of benefit not only at the individual level, improving quality of life and increasing activities of daily living, but also at the national level: with individuals returning to work following their operations, they will be able to regenerate the costs of their procedure and subsequently contribute to mainstream economic activities, increasing the GDP. Evidently, therefore, it is an investment worth making.

Chapter Seven

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Appendix A

Ethics Approval

Université d'Ottawa
Bureau d'éthique et d'intégrité de la recherche

University of Ottawa
Office of Research Ethics and Integrity

Ethics Approval Notice

Health Sciences and Science REB

Principal Investigator / Supervisor / Co-investigator(s) / Student(s)

First Name	Last Name	Affiliation	Role
Raywat	Deonandan	Health Sciences / Others	Principal Investigator
MacKenzie	Turpin	Health Sciences / Others	Student Researcher

File Number: H02-11-08

Type of Project: Secondary use of data

Title: Evaluation of Ophthalmological Clinical Database from India

Renewal Date (mm/dd/yyyy)	Expiry Date (mm/dd/yyyy)	Approval Type
08/03/2013	08/02/2014	Ia

(Ia: Approval, Ib: Approval for initial stage only)

Special Conditions / Comments:
N/A

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Appendix B

Editor's letter of support for published article

Revue interdisciplinaire des sciences de la santé
Interdisciplinary Journal of Health Sciences
Université d'Ottawa | University of Ottawa
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March 18, 2015

Interdisciplinary School of Health Sciences
Faculty of Health Sciences
University of Ottawa

To Whom It May Concern,

Please be advised that the editors of the Interdisciplinary Journal of Health Sciences have given their permission to MacKenzie Turpin to reproduce within his Master's thesis his manuscript titled, "The epidemiology of ophthalmological disease among school age children in rural India", which was published in our journal in 2014 in volume 4, issue 1, in pages 45-48.

Yours respectfully,

Arlanna Pugh
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