Distribution Agreement

In presenting this thesis or dissertation as a partial fulfillment of the requirements for an advanced degree from Emory University, I hereby grant to Emory University and its agents the non-exclusive license to archive, make accessible, and display my thesis or dissertation in whole or in part in all forms of media, now or hereafter known, including display on the world wide web. I understand that I may select some access restrictions as part of the online submission of this thesis or dissertation. I retain all ownership rights to the copyright of the thesis or dissertation. I also retain the right to use in future works (such as articles or books) all or part of this thesis or dissertation.

Signature:

_____ _____

Meredith Lichtenstein Date

Cataract-Related Visual Impairment and Cataract Surgery: Geographic Disparities Between Five Sudanese States

By

Meredith Lichtenstein
Master of Public Health

Epidemiology

_____

Carolyn Drews-Botsch
Faculty Thesis Advisor

_____

Susan Lewallen
Thesis Field Advisor

Cataract-Related Visual Impairment and Cataract Surgery: Geographic Disparities Between Five Sudanese States

By

Meredith Lichtenstein

B.A.
Emory University
2010

Faculty Thesis Advisor: Carolyn Drews-Botsch, PhD, MPH

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirement for the degree of
Master of Public Health
In Epidemiology
2012

ABSTRACT

Cataract-Related Visual Impairment and Cataract Surgery: Geographic Disparities Between Five Sudanese States

By Meredith Lichtenstein

Objective: To determine the differences in the prevalence and leading causes of bilateral blindness and visual impairment, barriers to cataract surgery, and cataract surgical coverage between Kassala, Northern, North Kordofan, Sennar, and White Nile states in Sudan.

Methods: The Rapid Assessment of Avoidable Blindness (RAAB) survey methodology, a multistage cluster sampling design, was utilized to gather data on visual acuity, causes of vision loss, reasons for untreated cataract, and details about past cataract surgeries. Data were analyzed using SAS-Callable SUDAAN.

Results: A total of 10,499 eligible subjects were included in the analysis, and 550 suffered from bilateral vision loss. The prevalence of bilateral blindness ranged from 6.34 cases per 1,000 people in the Northern state to 13.10 cases per 1,000 people in Kassala. Cataract was the leading cause of all levels of vision loss in each state, and more than 80% of blindness and 85% of vision loss could have been avoided. Cost was the most popularly reported barrier to cataract surgery. Other important barriers included absence of surgical services, no knowledge of treatment, and awaiting cataract maturity. Cataract surgical coverage rates were moderate in each state, the lowest in Kassala and the highest in the Northern state. IOL implant surgery was most widely performed. Most cataract surgeries were performed in government hospitals, and eye camps and improvised settings were significantly more likely to provide surgical services free of charge. Patient satisfaction was significantly correlated with the type of surgery received.

Conclusions: Further efforts are needed in Sudan to help reach the goal of the VISION 2020 initiative to eliminate all avoidable global blindness. Based on the barriers to cataract surgery, educational efforts should target visually impaired groups to increase knowledge of treatment options and access to surgical services. Hospitals should work closely with community ophthalmology organizations to offer and promote discounted surgical services. Finally, to prevent further disparities between cataract surgery qualities, traditional surgery settings and couching practices should be the target of future interventions.

Cataract-Related Visual Impairment and Cataract Surgery: Geographic Disparities Between Five Sudanese States

By

Meredith Lichtenstein

B.A.
Emory University
2010

Faculty Thesis Advisor: Carolyn Drews-Botsch, PhD, MPH

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
In partial fulfillment of the requirements for the degree of
Master of Public Health
In Epidemiology
2012

ACKNOWLEDGEMENTS

I would like to thank Dr. Kamal al Binnawi from the Federal Ministry of Health in Sudan and Dr. Susan Lewallen from the Kilimanjaro Centre for Community Ophthalmology for collecting and providing me with the opportunity to work with these data. I would also like to thank Dr. Carey Drews-Botsch, Paul Weiss, and Jena Black for their support, caring, and guidance. It was a privilege to work with all of you.

TABLE OF CONTENTS

BACKGROUND

The World Health Organization (WHO) in Geneva, Switzerland estimates that as of 2010, approximately 285 million people globally are visually impaired and 39 million of those are blind (1). These numbers show an approximate 10% decrease from the 2004 estimates of 314 million suffering from visual impairment, including 45 million blind individuals (2). This decrease may reflect a real improvement or may be the result of newly available data because the 2004 estimates were based on extrapolated data.

More than 80% of the world's visual impairment is preventable or treatable, and 90% occurs in low- and middle-income countries (2). Main causes of visual impairment can result from issues of the eye itself (e.g. refractive error, corneal scarring, or any abnormality of the eye), age-related issues (e.g. glaucoma, age-related macular degeneration [ARMD], cataract), infectious diseases (e.g. trachoma, onchocerciasis), chronic diseases (e.g. diabetic retinopathy), and surgical complications (3).

The economic costs associated with blindness and visual impairment are substantial. These include costs of lost labor productivity, such as unemployment costs and costs for caregivers, and eye care health programs including their direct costs and indirect costs of necessary equipment. On top of the economic costs, there are personal cost losses due to the suffering and premature death caused by blindness. The International Agency for the Prevention of Blindness (IAPB) estimates that in 2010, the total loss of productivity associated with blindness was

at least $200 million, and if no improvements are made to the state of vision care around the world, by 2020 the cost of productivity losses would increase to at least $300 million (4).

Cataract is a partial or complete opacity of the crystalline lens resulting in blurred vision, loss of visual function, and eventually blindness (5). Cataracts can be either bilateral or unilateral and can result from age, disease or trauma. While some cataracts are congenital or result from trauma in younger individuals, most develop in older individuals. No matter the origin, cataract is the leading cause of blindness, resulting in 51% of the total cases (1).

To treat or prevent blindness once the lens has become opacified, the only way to recover vision is cataract surgery to remove the lens. In developed countries, the lens is usually replaced with a synthetic intraocular lens (IOL), while non-IOL surgery is more common is less developed regions. Without the placement of an IOL, contact lenses or aphakic glasses must be used to focus light on the retina.

A variety of lens removal procedures are available. Intracapsular cataract extraction (ICCE) involves the complete removal of the lens and lens capsule coupled with the insertion of an IOL in the anterior chamber of the eye or the use of non-IOL correction. The removal of the lens capsule is an advantage of ICCE because it eliminates the risk of capsule opacification. Extracapsular cataract extraction (ECCE) was developed in the early 1980s, and although the lens is removed, the extraction does not include the posterior lens capsule. With ECCE, a posterior chamber IOL can be placed within the capsular bag. The remaining capsule may reduce the risk of complications in the posterior segment, though it is still subject to

potential opacification. ECCE involves either phacoemulsification, the ultrasonic breakage of the lens nucleus, or manual breakage, which is a more difficult technique than a standard ECCE but less costly than phacoemulsification (6). Couching, the manipulation of the lens with a needle in order to loosen and detach the lens is no longer widely used except in traditional or poorly resourced settings. The detached lens then sinks into the vitreous humor, allowing light to reach the retina (7).

More than half of all blindness is related to cataract. Thus, a substantial portion of the economic costs associated with blindness and vision impairment results directly from cataracts. A study by P. Desai et al. assessed gains in visual function and in quality of life after cataract surgery. The results indicated that within a short span of four months post-surgery, patients experienced significant gains in visual function, defined as functioning in vision dependent activities in everyday life, and in patient-perceived quality of life, which was measured by a standardized sickness impact profile (8). Therefore, economic and personal losses can be reversed quickly after cataract surgery, and those previously blind individuals can begin to contribute to their personal lives and to society.

VISION 2020: the Right to Sight

VISION 2020 is a joint initiative by the WHO and the IAPB and was introduced in 1999. Its main goal is to eliminate worldwide avoidable blindness by the year 2020. The initiative focuses on cataract; trachoma; onchocerciasis; refractive error and low vision; childhood blindness, including vitamin A deficiency;

and, in developed regions where aforementioned conditions are controlled, glaucoma, and diabetic retinopathy. In order to achieve the VISION 2020 goals, each country needs to have a national blindness prevention committee that manages programs in the VISION 2020 agenda and develops national action plans. These plans are to be updated at five-year intervals. Diseases will be prioritized with the input of the country's government, public health specialists, ophthalmologists, and non-governmental organizations (NGOs); and the plan must be adopted by the government. This sets the stage for surveillance, training, and intervention programs. Regional reports are also drafted every five years for each of the seven IAPB regions: Africa (consisting of sub-Saharan Africa), Eastern Mediterranean (countries including and in between Morocco and Pakistan), Europe (all countries east of the eastern tip of Siberia and Greenland), North America (Canada, the Caribbean, and the United States), South America (comprised of all Central and South American countries), Southeast Asia (India, Nepal, Bangladesh, Timor Leste, Myanmar, Bhutan, Maldives, Indonesia, Sri Lanka, Thailand, and Democratic People's Republic of Korea), and Western Pacific (countries in Eastern Asia as well as all remaining island nations in the Pacific Ocean) (9).

As of 2010, VISION 2020 planning workshops have been held in 151 countries, which have led to the creation of national blindness prevention committees in more than 118 of these countries. 104 countries have successfully created national VISION 2020 action plans (4). These efforts have had a positive impact on worldwide blindness and visual impairment, which may be reflected in the observed decreases in prevalence between 2004 and 2010. The advocacy and

promotional efforts for eye health and blindness prevention have helped improve the quality of life and increase the average income of visually impaired individuals and their families (4). However, to reach the 2020 goals, further advocacy, funding, and data are necessary. The WHO issued a future action plan for the years 2009 through 2013 that addresses the needs for political and financial commitment to the initiative, stronger partnerships and coordination, and increased data collection, analysis, and circulation.

For many developing countries, there are few adequate and up-to-date data on the prevalence of avoidable blindness and visual impairment. Baseline data at the district and state levels are paramount for planning, funding, monitoring, and programmatic services. Fortunately, through VISION 2020 and the multiple NGOs involved with reducing global blindness, surveys and blindness studies are being performed in many developing countries to help assess the actual state of blindness in the developing world. Gathering these data will benefit the initiative so that each country per IAPB region can develop and carry out national action plans. In Africa, one of these organizations is the Kilimanjaro Centre for Community Ophthalmology (KCCO) in Tanzania, whose mission is to eliminate avoidable blindness through sustainable community ophthalmic services, programs, research, and training.

Rapid Assessment of Avoidable Blindness

The Rapid Assessment of Avoidable Blindness (RAAB) survey methodology was designed by the International Centre for Eye Health in London and has been widely used in developing countries (10). Development of the RAAB survey

spawned from the need for a faster, cheaper, and straightforward blindness survey methodology in the field. Typical blindness surveys require high levels of ophthalmic expertise that escalate costs. Further, given these high costs, repeat assessments could not be undertaken to evaluate intervention program effectiveness even in places where baseline surveys could be completed.

A RAAB survey, conducted at the district level, surveys approximately 2500 to 5000 individuals aged 50 years and older. This age limit was chosen because worldwide, 82% of all blind individuals are in this age group (1). Visual acuity is measured for each sampled subject, and those considered visually impaired by WHO standards are further examined by an ophthalmologist. Causes of visual impairment are recorded. Finally, if the ophthalmologist finds evidence of cataract or cataract surgery, detailed information is gathered to assess location and quality of surgery or barriers to cataract surgery (3). In order to be 'rapid,' a RAAB survey utilizes local staff and basic ophthalmic equipment that is easy to use and affordable. Complex ophthalmic assessments, such as visual fields or intraocular pressure, are not necessary to diagnose the main conditions of interest.

RAAB surveys can produce estimates of the prevalence of blindness and visual impairment due to either unavoidable or avoidable causes; the main causes of blindness and visual impairment; cataract surgical coverage; quality of cataract surgery, and barriers to cataract surgery. These estimates are important for the planning and monitoring of eye care services, while the surgical quality and barriers to surgery are important for maintenance of high quality cataract surgical services, high coverage, and for the planning of future cataract surgical services (3).

Since the development and publication of the RAAB survey methodology in 2006, RAAB survey studies have been mostly performed in Africa and Southeast Asia. The African surveys were conducted in Southern Malawi; Kilimanjaro Region, Tanzania; Nakuru District, Kenya; Western Province, Rwanda; and Eritrea. In each of these studies, the majority of all cases of blindness, severe visual impairment, and visual impairment were attributed to cataract (11-15).

Most of northern Africa lacks baseline vision health data. Sudan is considered a part of the Eastern Mediterranean region in the VISION 2020 initiative. Sudan has successfully participated in a planning workshop, instituted a national blindness prevention committee, and developed a government-approved national action plan (16). Currently, Sudan has two blindness control programs focusing on infectious disease-related blindness: the National Trachoma Control Program and the National Onchocerciasis Control Program. There is also a national prevention of blindness unit within the Federal Ministry of Health that is responsible for coordinating all blindness prevention activities. The major issues and obstacles surrounding further eye care programs for blindness prevention efforts were political strife and unrest within this region (17).

Cataract, Cataract Surgery, and Avoidable Blindness in Sudan

The Sudanese Ministry of Health saw the need for surveys and performed five RAAB surveys in the following Sudanese states: Kassala, North Kordofan, Sennar, White Nile, and the Northern State. This was the first effort in Africa to survey multiple states within one country during the same time frame. These RAAB

survey results were analyzed in order to meet the four main goals of this study. The first was to determine the prevalence of blindness and visual impairment and the proportions of which were attributable to untreated cataract. The second was to determine barriers to cataract surgery in individuals with untreated cataract. The third was to analyze cataract surgery details and identify differences between states. The final goal was to suggest future actions to support the VISION 2020 goals based on the findings of these surveys.

METHODS

Definitions of Blindness and Visual Impairment

Snellen visual acuity is interpreted as the greatest distance a subject can successfully read a line on the Snellen eye chart (the numerator, e.g. 3 meters) over the distance a "normal" observer can successfully read the same line (the denominator, e.g. 60 meters) (18). Visual impairment is defined as a visual acuity between 3/60 and 6/18 (3). The WHO defines blindness as a visual acuity less than 3/60 in the better eye with the best correction based on the Snellen metric eye chart (3).

RAAB Survey Methodology

RAAB survey areas can be an entire country or a portion of the country such as a province or county. For the current survey, Kassala State, Northern Kordofan State, Northern State, Sennar State, and White Nile State, Sudan were chosen for study. According to the Central Bureau of Statistics of Sudan, each of these states have populations ranging from approximately 699,000 in Northern State to 2.9 million in North Kordofan. The 2008 Sudanese Census was used to create the sampling frame in each state, from which clusters were systematically selected. A multistage cluster sampling methodology was used, which incorporated the random selection of population units or clusters from an enumerated list containing all population units, which were then divided into segments of equal populations of fifty individuals aged 50 years and older. Individual households within clusters were

selected via compact segment sampling. The number of selected segments of 50 people was proportional to the number of people aged 50 years and older reported in the census for that population unit. Segments were selected at random and these represented the clusters within the survey area. All households within a cluster were sequentially included in the sample until 50 people aged 50 or older were surveyed. Segment sampling continued until 50 people had been surveyed (3). These procedures were repeated for the number of clusters required to meet the needed survey sample sizes. The necessary sample size per survey depended on the expected prevalence of blindness in each state, the required precision around said prevalence estimates, the desired level of confidence, the sampling method, and the cluster size and number of clusters (3). Surveyors assumed that the expected prevalences of blindness between the five states were uniform and equal to 7% ±1.4%. The required precision was relative to the prevalence estimates (±20%) with 95% confidence. The calculated design effect equaled 1.5 and the non-response rate for the sample size calculation was 5%.

Eligibility of individuals depended on age and whether or not they resided in the household for at least six out of twelve preceding months. For all eligible individuals, the surveyors completed RAAB survey questionnaires, but further examination was voluntary. Completed questionnaires reported whether an individual was successfully examined, if he/she refused to be examined, if he/she was absent or unavailable for examination, or if he/she was unable to communicate due to deafness, dementia, or psychiatric illness. A complete examination included visual acuity measurement in each eye with and without a pinhole, and examination

of each lens. To measure visual acuity, the examiner held a tumbling E-chart in full daylight at varying distances from the subject who stood in the shade or with his/her back to the sun while being examined. If the subject normally wore distance glasses, then the glasses were worn during the examination. Each eye was measured separately. The subject was required to point in the direction of the open ends of the letter E. First, an E of size 6/60 (distance of six meters with E of size 60 of the Snellen chart) was shown six meters away from the subject. If this size could be seen at a distance of six meters, then the examiner showed an E of size 6/18. If the 6/18 E could be seen, then the subject had no visual impairment. If the 6/18 E could not be seen, then the subject had visual impairment (VI). If the subject could not see the E of size 6/60, then the E was shown at a distance of three meters from the subject (size 3/60) and if 3/60 E could be seen, then the subject had severe visual impairment (SVI). If the 3/60 E could not be seen, then the E was moved to one meter away from the subject (size 1/60), but anything less than the ability to see the 3/60 E was considered blind [Appendix A]. Each subject's VA was recorded at a certain level if the subject correctly identified four out of five showings of the E-chart. Only subjects with VA levels less than 6/18 were re-examined using a pinhole (while wearing glasses, if applicable). Pinhole VA could not be worse than the recorded presenting VA in an individual.

After measuring VA, each subject was taken inside his/her house for lens examination. Using a direct ophthalmoscope and a flashlight, the lens of each eye was assessed from approximately twenty to thirty centimeters away in a semi-dark area of the home. Examiners specifically looked for any evidence of untreated

cataract, which would present itself as a gray or white pupil, or evidence of any previous cataract surgery, such as aphakia (an absent lens), pseudophakia (absent lens replaced with an IOL) with or without posterior capsule opacification (PCO). A complete lens examination allowed the examiner to identify main causes of visual impairment and/or blindness in visually impaired subjects, by eye and overall per person.

When recording main causes of visual impairment by eye or by person, if there were two disorders, one primary and one secondary, then the primary disorder was recorded. If there were two co-existing primary disorders, then the disorder that should be more easily curable or preventable was recorded as the principal cause. Possible causes were divided into two groups: totally avoidable (including curable and/or preventable causes) and potentially avoidable. Curable causes included refractive error, untreated cataract, and uncorrected aphakia; preventable causes includes surgical complications, trachoma, phthisis, corneal scarring, and onchocerciasis; and potentially preventable causes include globe abnormalities, glaucoma, diabetic retinopathy, age-related macular degeneration, or other posterior segment issues or central nervous system disorder.

The age at surgery, place of operation, the type of surgery, costs and satisfaction with surgery, and cause of low vision after surgery were recorded for subjects who had undergone cataract surgery. Types of locations at which cataract surgeries were performed included government hospitals, voluntary or charitable hospitals, private hospitals, eye camps or improvised settings, and traditional settings. Names of hospitals were not included. Surgery at an eye camp constituted

a surgery performed by a qualified ophthalmic staff member in an improvised operation location, while a traditional setting referred to a surgery performed either at home or at the premises of a 'coucher' or traditional healer. Types of surgery included non-IOL, with which an IOL was not implanted at the time of surgery; an IOL implant; or couching, which was recorded if there was evidence of lens dislocation and quavering of the iris, or if couching was reported in the subject interview. Costs of surgery were recorded as free, partially free, or paid-in-full. Patient satisfaction with cataract surgery was recorded on a numeric scale, the numbers one corresponding to high satisfaction, three corresponding to indifference in satisfaction, and five corresponding to high dissatisfaction. Lastly, if an individual continued to have low vision post-surgery, then related causes were recorded, including refractive error, ocular comorbidity, surgical complications, and long-term sequelae.

For subjects who were found to have untreated cataracts during their lens examinations, the main two reasons for failure to get operation were recorded. These reasons, or barriers to cataract surgery, typically involve a lack of services, poor accessibility, costs of surgery, no knowledge of treatment or of how to pursue surgery, personal beliefs and fears, and previous instruction to wait for cataract maturity.

Data Analysis

KCCO provided the five separate RAAB survey datasets in Excel spreadsheet format. These were combined and explored using SAS version 9.3 (SAS Institute,

Cary, NC). At the time of each survey, subjects within a cluster were provided an 'individual number' between 1 and 50 or 51 depending on the number of sampled individuals in each cluster. Observations with inappropriate individual numbers had no data for the variables of interest, and all were excluded. All observations with missing data on examination status were also excluded.

This study does not utilize the typical software designed to analyze RAAB survey data. In order to correctly analyze this cluster sampling design, SAS-Callable SUDAAN (Release 10.0.1, RTI International, Research Triangle Park, NC) was used. To properly use SUDAAN, every observation within the compiled dataset required a sampling weight. By sampling the populations with the RAAB sampling design, the survey sample can be considered an EPSEM sample (Equal Probability of Selection for Each Member), with which every element in the sample is independent with identical distributions and has equal sampling probabilities. Therefore, every observation was given a sampling weight equal to 1. Because of the complex sample design parameters associated with the stratified cluster design of this study, SUDAAN takes into account the sampling probabilities in order to compute the most accurate and robust variance estimates. To calculate and compare statistics of cataract and cataract surgery, only those subjects who were examined were of interest, but non-examined observations were not excluded in order to maintain the correct, SUDAAN-generated variance estimates.

Survey coverage was calculated by dividing the number of examined individuals by the total number of sampled individuals by state. Survey non-

response rates were calculated by sex per state and included all absent or unable-to-communicate individuals and those who refused to be surveyed.

To determine significant differences in proportions and odds ratios (ORs) between sexes and across states, descript, crosstab, and rlogist procedures were used to run two-sample t-tests and chi-squared tests of proportions. Analyses were limited to bilateral cases of vision impairment as defined by the best visual acuity in the better eye using a pinhole. These limited analyses included calculations of visual impairment (VI, SVI, and blindness) prevalence, determining principal causes of each level of visual impairment, as well as the specific cataract-related cases of vision loss. Because of the nature of posterior segment issues in the eye, these potential causes of vision loss were grouped together into one category for analysis, and these include glaucoma, diabetic retinopathy, are-related macular degeneration, globe abnormalities, and other posterior segment/CNS disorders. Also, only the bilateral cataract-related cases of vision loss were used to determine the main barriers to cataract surgery.

Cataract surgical coverage was used to measure the proportion of people in the survey area who were blind or visually impaired due to cataract, which had been operated in one or both eyes, compared to the number who required cataract surgery. It was calculated for persons only for any level of vision loss, using the following equation (3):

$$\textit{Cataract Surgical Coverage Persons (\%)} = [(x+y)/(x+y+z)]*100$$

where x was the number of people with one operated and one visually impaired eye; y was the number of people with bilateral aphakia or pseudophakia; and z was the number of bilaterally visually impaired by cataract (for a specific level of vision).

Details about cataract surgeries in the sample population of each state were reported by person and were determined by each individual's first cataract operation. For each state, types of surgery and places of operation for all operated 'first' eyes were first looked at separately. Next, the types of surgery by place of operation, costs of surgery by location of operation and by type of surgery, and surgery satisfaction by surgery type were reported.

RESULTS

The five RAAB surveys were conducted during 2009 and 2010, each completed in less than two weeks' time. A total of 59 observations within the combined dataset were excluded due to inappropriate individual identification numbers or missing examination statuses. In the overall study, 10,499 eligible individuals were included, with 2145 from Kassala State, 2049 from Northern State, 2150 from North Kordofan, 2005 from Sennar, and 2150 from White Nile State. The highest survey coverage was in White Nile State (97.53% of sampled individuals completed the interview and were clinically examined), while the lowest survey coverage was in North Kordofan (94.51%) [Table 1]. The largest survey non-response rate was from men in North Kordofan. The primary reason that surveys were not completed was that sampled individuals were not at home (<4% of sampled individuals). Less than 1% of sampled individuals refused to participate, and less than 1.5% were unable to communicate.

The age of examined individuals ranged from 50 to 99 years in every state (Table 2). There were significant mean age differences among examined individuals in Kassala, Northern State, and North Kordofan (p-values <0.0000, 0.0307, and 0.0002 respectively). There were no significant differences in age by sex in those individuals who were unexamined in each state.

Overall, the prevalence of bilateral blindness in the study was 10.10 cases per 1,000 people (95% CI: 8.14, 12.06). There were 106 bilaterally blind individuals in the study. The largest portion of these cases was found in Kassala (28 cases) [Table

3], which gave a sample prevalence of blindness of 13.10 cases per 1,000 people (95% CI, 7.37, 18.74) [Table 4]. Northern State had the lowest number of cases and prevalence of blindness (6.34 cases per 1,000 people [95% CI: 3.21, 9.48]). The prevalence of bilateral severe visual impairment in the study was 7.14 cases per 1,000 people. There were 75 bilateral cases of SVI, the highest prevalence of which was in White Nile State with 10.70 cases per 1,000 people (95% CI: 5.60, 15.79). Finally, the prevalence of bilateral visual impairment was 35.15 cases per 1,000 people. There were 369 bilateral cases of visual impairment, and while Kassala and White Nile both had 90 cases each, Kassala had the highest prevalence of VI with 41.96 cases per 1,000 people (95% CI: 31.37, 52.54). Between men and women, the prevalence of blindness was similar in Kassala and Northern State, but in North Kordofan, men had more than twice the number of cases, and there were more cases in women than in men in Sennar and White Nile States.

Upon lens examination for all levels of vision, bilateral cataract was found in 923 individuals; bilateral aphakia was found in 106 individuals; bilateral pseudophakia without PCO was found in 135 individuals; and bilateral pseudophakia with PCO was found in 21 individuals [Table 5]. The prevalence of bilateral cataract was similar between men and women in each state. More men had bilateral aphakia than women in each state, but the difference was only significant in White Nile State. The prevalence of pseudophakia with or without PCO was slightly more variable than that of cataract, but none of these differences were significant.

Cataract was the leading cause of all levels of visual impairment in each of the

five states [Tables 6, 7, 8]. Specifically, out of the 106 cases of bilateral blindness, 78 individuals had cataract reported as the principal cause of blindness, and 60 of those had cataracts in both blind eyes [Table 9]. For individuals with SVI or VI, the proportions of cataract as the principal cause of the respective level of vision loss were similar to that for bilaterally blind individuals, though the proportion of bilateral cataracts within the SVI and VI groups was greater than 90%. Of all the potential causes of vision loss, the posterior segment disorders were the only to be considered unavoidable. When combined to form one group, they represented the second most frequently reported cause, though their prevalence was consistently less than one-fifth of the total bilateral cases of vision loss in every state. Therefore, more than 80% of all cases of bilateral vision loss were avoidable.

Overall, the most popularly chosen barrier to cataract surgery in the whole study population was the inability to afford the operation (977 people, 39.14%). Other significant impediments to cataract surgery included: 'told to wait for cataract to mature' (439 people, 17.59%); no knowledge of treatment or how to get surgery (353 people, 14.14%); need not felt (200 people, 8.01%); and absence of surgical services (158 people, 6.33%) [Table 10].

As the level of vision loss became less severe, the top barriers to cataract surgery shifted in importance [Table 11]. The inability to afford the surgery remained the predominant barrier. Unawareness of treatment or of how to get surgery, the lack of surgical services, and 'no need felt' were reported more frequently among individuals with either blindness or SVI compared to those with VI. More individuals with VI were told to wait for their cataracts to mature than

either of the worse VA levels, and the VI group was the only group for which personal beliefs was one of the top five barriers.

Cataract surgical coverage, the percent of individuals who received surgery compared to those who need surgery, ranged from 59.84% in men in Kassala, to 78.90% in women in the Northern State [Table 12]. A total of 923 first eye cataract surgeries had been performed in study subjects. Most of these cataract surgeries were performed in government hospitals in every state; however, in Kassala, North Kordofan, and Sennar, the second larger portion of surgeries were performed in improvised settings or eye camps, while in the Northern State and White Nile State, private hospitals and voluntary/charitable hospitals respectively performed the second largest portions of surgeries [Table 13]. Few surgeries were performed in the traditional type of setting. Of the three types of cataract surgery, surgery with IOL implant was the most common with 714 surgeries [Table 14]. Fewer than 100 non-IOL surgeries were reported in each state. The highest number of couching surgeries was reported in Kassala and North Kordofan (6 cases each) while the Northern State had none.

All comparisons of types of surgery used the White Nile state as the referent state. Non-IOL surgeries were less likely to be performed in all other states, though the OR was only significant in Sennar (OR_{Sennar}= 0.35 [95% CI: 0.20, 0.61]). IOL implant surgeries were significantly less likely to be performed in North Kordofan only ($OR_{North\ Kordofan}$=0.69 [95% CI: 0.48, 0.99]), while IOL implant surgeries were more likely (though not significantly) to be performed in the Northern state. Couching surgeries were more likely to be performed in all other states, though

none of these associations were significant [Table 15].

Individuals who received either non-IOL or IOL implant surgeries were significantly more likely to highly rate their satisfaction with their surgery than those who received couching ($OR_{non\text{-}IOL}$=5.38 [95% CI: 1.85, 15.64], $OR_{IOL\ implant}$=14.72 [95% CI: 5.10, 42.47]) [Table 16]. When comparing cost of surgery to place of operation using the traditional setting as a referent, only eye camps/improvised settings were significantly more likely to provide cataract surgical services free of charge ($OR_{Eye\ Camp}$=100.33 [95% CI: 24.48, 411.18]) [Table 17]. No other association between satisfaction and surgery type or cost of surgery and place of operation was found to be significant.

DISCUSSION

This study has shown that cataract is the leading cause of vision loss in each of the five Sudanese states. The estimated prevalence of blindness in these states was less than the expected prevalence of 7%±1.4% that was incorporated into the RAAB survey design. These findings are similar to previous RAAB studies in African countries (11-15). Only bilateral cases of blindness, SVI, and VI, and bilateral cases of cataract were studied. More than 80% of blindness in all five states and more than 85% of all levels of vision loss could have been avoided. Mean ages of individuals with bilateral cataracts with any level of VA were higher than the mean ages of examined individuals in general. This finding supports the evidence that with older age comes greater risk of cataract, even in developing countries (19).

The leading barrier to cataract surgery was the cost of surgery. Other highly reported barriers include the lack of surgical services in general, no knowledge of treatment or how to access treatment, and awaiting cataract maturity. Knowing these barriers will allow the VISION 2020 national blindness prevention committee in Sudan to tailor who and where to target prevention efforts in amendments to the Sudanese VISION 2020 national plan. To address cost issues, government and private hospitals could consent to and promote half-price surgical services. Their ophthalmic staff could also support and operate volunteer remote eye camps to increase surgical service access in rural areas of the country. Unfortunately, the ratio of ophthalmologists in the population of developing countries is low, which could lead to issues in implementing these types of volunteer services (19). By

offering professional training or further education to ophthalmic support staff, the burden of routine examinations (and potentially surgeries) on ophthalmologists in this region could be lessened. Although offering free or lower priced surgeries should attract more people to access treatment, two previous studies in rural Kenya showed that only 70% of blind or visually impaired individuals accepted free ICCE surgery (20) and that lower visual acuity is not a strong predictor of acceptance of free surgical services (21). Further research needs to be completed to determine how to successfully encourage use of cataract surgical services. To address blind individuals who are unaware of treatment or of how to get treatment, these groups need to be targeted with surgical services advertising and education. Individuals who have been told to postpone surgery until their cataracts have matured could be subject to personal costs and sacrifices if while waiting for cataract maturity, their productivity and ability to benefit society decrease. Recommendations should be made for an acceptable earlier age for cataract removal, which would lead to more years of productivity population groups throughout the country. Because the top barriers to cataract surgery differed between levels of VA, education and interventions need to target groups based on VA levels.

Cataract surgical coverage for each state was moderate (ranged between approximately 60-79%). Coverage rates were similar between men and women in the Northern State and in White Nile, but rates were most divergent in Kassala and Sennar states. In both of these states, women had higher coverage, which contrasts RAAB studies from Southern Malawi, Nakuru district, Kenya, Kilimanjaro region, Tanzania, and Eritrea, which all found higher coverage rates among men. This

difference could be attributable to differences in barriers to surgery between men and women. For example, only men who had bilateral blindness, SVI, or VI reported not having time to get surgery.

A large proportion of surgeries performed in eye camps or improvised settings were provided free of charge, which supports the recommendation of working with hospitals to lower surgery costs and coordinating volunteer eye camps in rural settings. The differences seen in satisfaction based on surgery types show that the different types of surgery do not produce equal outcomes. Couching, which was only performed in traditional settings, was strongly associated with low levels of patient satisfaction. Traditional settings and couching methods should be the target for future interventions in order to promote more advanced and reliable (in terms of satisfaction and costs) surgical techniques.

Strengths

This is the first study to compare RAAB survey results from multiple states within the same country. This allows both researchers and policy makers to compare blindness causes, barriers to cataract surgery, and surgery details across states to better target individuals in need of vision services. SAS-callable SUDAAN allowed for the data analysis to take into account the complex cluster survey study design. This study also utilized the most recent census completed by Sudan at the time of the surveys, leading to good accuracy of the enumerated populations within each state.

Weaknesses

This study was limited by excluding unilateral cases of vision loss and cataract from the analysis, which could lead to an underestimation of the total cataract and blindness/SVI/VI prevalences in all eyes within the study. Because surveyors chose which disorders to report based on either the presence of a more easily treatable or preventable co-existing primary disorder or if cataract was considered secondary to another disorder, the total number of cataract could be further underestimated. In the situation where two disorders were co-existing at the same magnitude of severity, vision might not be restored even if the more easily preventable or treatable disorder were repaired. If this were the case, the surveyor's choice would also lead to an overestimation of the total amount of avoidable vision impairment. Responses to questions not answered through the ophthalmic examination (those about surgery barriers and details of cataract surgery) could be affected by reporting or recall bias. This limitation has been addressed previously, disclosing that patient responses to these types of questions are not validated, but are still useful in planning for cataract services (11).

Conclusions

Despite the lower prevalence of blindness and the moderate cataract surgical coverage in each Sudanese state included in this study, this does not mean that efforts to reduce blindness and increase cataract surgical coverage should be discontinued. The low prevalence could be partly attributable to the already established Sudanese VISION 2020 national plan. Further efforts are needed to

address disparities between levels of vision loss of barriers to cataract surgery and in cataract surgical access and quality.

REFERENCES

1. WHO. New Estimates of Visual Impairment and Blindness: 2010. 2010.
2. WHO. Action Plan for the Prevention of Avoidable Blindness and Visual Impairment, 2009-2013. 2009.
3. International Centre for Eye Health. Rapid Assessment of Avoidable Blindness Instruction Manual. ICEH, 2007.
4. IAPB. 2010 Report. London, England, 2010.
5. Diagnosis Code 366, ICD-9-CM: International Classification of Diseases, 9th Revision; Clinical Modification, 6th edition, 2006. Los Angeles, CA: Practice Management Information Corporation, 2005.
6. Riaz Y, Mehta, JS, Wormald, R, Evans, JR, Foster, A, Ravilla, T, Snellingen, T. Surgical interventions for age-related cataract. Cochrane Database of Systematic Reviews, 2006.
7. Swan HT. An ancient record of 'couching' for cataract. Journal of the Royal Society of Medicine 1995;88(4):209-10.
8. Desai P, Reidy A, Minassian C, Vafidis G, Bolger J. Gains from cataract surgery: visual function and quality of life. British Journal of Ophthalmology 1996;80:868-73.
9. Pizzarello L, Abiose A, Ffytche T, Duerksen R, Thalasirag R, Taylor H, Faal H, Rao G, Kocur I, Resnikoff S. Vision 2020: The Right to Sight: A Global Initiative to Eliminate Avoidable Blindness. Archives of Ophthalmology 2004;122:615-20.

10. Dinneen B, Foster A, Faal H. A Proposed Rapid Methodology to Assess the Prevalence and Causes of Blindness and Visual Impairment. Ophthalmic Epidemiology 2006;13:31-4.
11. Kalua K, Lindfield R, Mtupanyama M, Mtumodzi D, Msiska V. Finding from a Rapid Assessment of Avoidable Blindness (RAAB) in Southern Malawi. PLoS ONE 2011;6(4):e19226.
12. Habiyakire C, Kabona G, Courtright P, Lewallen S. Rapid Assessment of Avoidable Blindness and Cataract Surgical Services in Kilimanjaro Region, Tanzania. Ophthalmic Epidemiology 2010;17(2):90-4.
13. Mathenge W, Huper H, Limburg H, Polack S, Onyango O, Nyaga G, Foster A. Rapid Assessment of Avoidable Blindness in Nakuru District, Kenya. Ophthalmology 2007;114(3):599-605.
14. Mathenge W, Nkurikiye J, Limburg H, Kuper H. Rapid Assessment of Avoidable Blindness in Western Rwanda: Blindness in a Postconflict Setting. PLoS Medicine 2007;4(7):e217.
15. Muller A, Zerom M, Limburg H, Ghebrat Y, Meresie G, Fessahazion K, Beyene K, Methenge W, Mebrahtu G. Results of a Rapid Assessment of Avoidable Blindness (RAAB) in Eritrea. Ophthalmic Epidemiology 2011;18(3):103-8.
16. WHO. VISION 2020: Global Initiative for the Elimination of Avoidable Blindness: action plan 2006-2011. Geneva, 2007.
17. IAPB. Council of Members Meeting Agenda Item 9: Regional Reports on VISION 2020 Achievements, Eastern Mediterranean Region. London: IAPB, 2011.

18. Schwiegerling J. Field guide to visual and ophthalmic optics. Bellingham, WA: SPIE Publications, 2004.
19. Brain G, Taylor H. Cataract blindness – challenges for the 21st century. Bulletin of the World Health Organization 2001;79(3):249-56.
20. Reshef D, Reshef SH. Postoperative cataract surgery satisfaction in a rural Kenyan clinic. Journal of cataract and refractive surgery 1997;23(4):575-80.
21. Briesen S, Roberts H, Ilako D, Karimurio J, Courtright P. Are Blind People More Likely to Accept Free Cataract Surgery? A Study of Vision-Related Quality of Life and Visual Acuity in Kenya. Ophthalmic Epidemiology 2010;17(1):41-9.

TABLES

Table 1: Eligible persons, examination status, and survey coverage and non-response rates by sex per Sudanese state.

		Total Eligible in Each State		Examined		Absent		Refused		Not capable of communication		Coverage by State	Survey Non-Response Rates by Sex and State
State	**Sex**	n	%	n	%	n	%	n	%	n	%	%	%
Kassala	Male	1068	49.79	1014	47.27	39	1.82	6	0.28	9	0.42	94.94	5.06%
	Female	1077	50.21	1036	48.30	19	0.89	8	0.37	14	0.65	96.19	3.81%
	Total	2145	100.00	2050	95.57	58	2.71	14	0.65	23	1.07	**95.57**	4.43%
Northern	Male	939	45.83	893	43.58	40	1.95	0	0.00	6	0.29	95.10	4.90%
	Female	1110	54.17	1059	51.68	33	1.61	4	0.20	14	0.68	95.41	4.59%
	Total	*2049*	*100.00*	*1952*	*95.26*	*73*	*3.56*	*4*	*0.20*	*20*	*0.97*	**95.27**	4.73%
North Kordofan	Male	1056	49.12	993	46.19	54	2.51	1	0.05	8	0.37	94.03	5.97%
	Female	1094	50.88	1039	48.33	25	1.16	7	0.33	23	1.07	94.97	5.03%
	Total	*2150*	*100.00*	*2032*	*94.52*	*79*	*3.67*	*8*	*0.38*	*31*	*1.44*	**94.51**	5.49%
Sennar	Male	1072	53.47	1044	52.07	20	1.00	6	0.30	2	0.10	97.39	2.61%
	Female	933	46.53	894	44.59	18	0.90	8	0.40	13	0.65	95.82	4.18%
	Total	*2005*	*100.00*	*1938*	*96.66*	*38*	*1.90*	*14*	*0.70*	*15*	*0.75*	**96.66**	3.34%
White Nile	Male	1090	50.70	1069	49.72	14	0.65	4	0.19	3	0.14	98.07	1.93%
	Female	1060	49.30	1028	47.81	18	0.84	5	0.23	9	0.42	96.98	3.02%
	Total	*2150*	*100.00*	*2097*	*97.53*	*32*	*1.49*	*9*	*0.42*	*12*	*0.56*	**97.53**	2.47%
Total for Study		*10499*		*10069*		*280*		*49*		*101*		95.90%	*4.10%*

Table 2: Average age of surveyed individuals, by examination status and sex, per state.

Examination Status		Examined		Absent		Refused		Unable to Communicate	
State	**Sex**	Mean	S.E. mean	Mean	S.E. mean	Mean	S.E. mean	Mean	S.E. mean
Kassala	Male	64.20	0.58	65.46	1.52	63.67	5.94	69.89	4.68
	Female	61.27	0.46	65.74	2.01	57.13	1.94	67.64	3.08
	p-value	<0.0000		0.9132		0.2787		0.6899	
Northern	Male	62.09	0.47	67.53	1.41	N/A	N/A	62.00	3.84
	Female	60.92	0.48	59.76	1.80	64.75	5.49	74.71	4.83
	p-value	0.0307		0.0011		N/A		0.0592	
North Kordofan	Male	63.59	0.56	65.93	1.59	55.00	0.00	73.25	4.80
	Female	60.85	0.61	60.04	1.59	59.71	2.97	71.78	3.26
	p-value	0.0002		0.0062		0.1135		0.8020	
Sennar	Male	63.39	0.54	62.85	2.23	64.17	5.39	68.00	1.43
	Female	62.62	0.66	65.11	3.08	59.25	4.29	77.00	4.71
	p-value	0.2287		0.5297		0.4690		0.0688	
White Nile	Male	63.15	0.57	69.36	2.83	55.50	1.84	74.67	9.32
	Female	62.03	0.56	61.06	2.22	63.60	6.76	64.33	5.71
	p-value	0.0719		0.0199		0.3187		0.4432	

S.E.= Standard Error

P-values testing differences in mean age between sexes in each state and each examination status.

Table 3: Prevalence of bilateral cases of vision loss (blindness, SVI, and VI), by sex per state.

State		Kassala						Northern						Northern Kordofan						Sennar						White Nile					
Sex		Male		Female		Total		Male		Female		Total		Male		Female		Total		Male		Female		Total		Male		Female		Total	
Level of Visual Acuity in the better eye, with pinhole (WHO definition)	Total Bilateral Cases	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.
Blindness VA<3/60																															
All Bilateral Cases	106	13	6.06	15	6.99	28	13.05	6	2.93	7	3.42	13	6.34	14	6.51	6	2.79	20	9.30	9	4.49	13	6.48	22	10.97	9	4.19	14	6.51	23	10.70
Severe Visual Impairment (SVI)- VA<6/60-3/60																															
All Bilateral Cases	75	11	5.13	7	3.26	18	8.39	8	3.9	3	1.46	11	5.37	7	3.26	3	1.40	10	4.65	6	2.99	7	3.49	13	6.48	13	6.05	10	4.65	23	10.70
Visual Impairment (VI)- VA<6/18-6/60																															
All Bilateral Cases	369	50	23.31	40	18.65	90	41.96	29	14.15	34	16.59	63	30.75	33	15.35	30	13.95	63	29.30	36	17.96	27	13.47	63	31.42	53	24.65	37	17.21	90	41.86

Prev.: Prevalences calculated per 1,000 people within each state.

Table 4: Prevalence of bilateral blindness within study population, by state.

State	Cases	Population	Prevalence per 1,000 people	Std. Error	Lower CL	Upper CL
Kassala	28	2145	13.05	2.90	7.37	18.74
Northern	13	2049	6.34	1.60	3.21	9.48
North Kordorfan	20	2150	9.30	2.30	4.79	13.81
Sennar	22	2005	10.97	2.50	6.07	15.87
White Nile	23	2150	10.70	2.10	6.58	14.81
All States	106	10499	10.10	1.00	8.14	12.06

CL= Confidence Limit, 95%

Table 5: Results of lens examination, by sex per state.

State	All States			Kassala					Northern					North Kordofan					Sennar					White Nile				
Sex	Male	Female	Total	Male	Female	p-value	Total		Male	Female	p-value	Total		Male	Female	p-value	Total		Male	Female	p-value	Total		Male	Female	p-value	Total	
Lens Examination	n	n	n	n	n	-	n	%	n	n	-	n	%	n	n	-	n	%	n	n	-	n	%	n	n	-	n	%
Normal	3421	3570	6991	611	680	-	1291	18.47	667	797	-	1464	20.94	673	784	-	1457	20.84	737	614	-	1351	19.32	733	695	-	1428	20.43
Opacity	472	451	923	124	115	0.54	239	25.89	53	53	0.26	106	11.48	89	88	0.75	177	19.18	99	94	0.5	193	20.91	107	101	0.84	208	22.54
Aphakia	64	42	106	18	14	0.57	32	30.19	9	13	0.63	22	20.75	7	3	0.33	10	9.43	11	7	0.54	18	16.98	19	5	**0.02**	24	22.64
Pseudoaphakia w/o PCO	67	68	135	13	10	0.49	23	17.04	20	24	0.49	44	32.59	6	7	0.8	13	9.63	11	15	0.34	26	19.26	17	12	0.45	29	21.48
Pseudophakia w/ PCO	11	10	21	1	3	0.42	4	19.05	4	1	0.14	5	23.81	1	1	0.98	2	9.52	0	2	0.16	2	9.52	5	3	0.51	8	38.10
Totals	4035	4141	8176	767	822	-	1589	19.43	753	888	-	1641	20.07	776	883	-	1659	20.29	858	732	-	1590	19.45	881	816	-	1697	20.76

Percents showing proportion of examination results contributed by each state.
P-values testing differences between males and females in each category and each state.

Table 6: Principal causes of bilateral cases of blindness, VA<3/60, by sex per state.

State	All States			Kassala			Northern			Northern Kordofan			Sennar			White Nile		
Sex	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Cause	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Refractive Error	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cataract, Untreated	33	45	78	10	13	23	2	4	6	10	6	16	4	12	16	7	10	17
Aphakia, uncorrected	2	0	2	0	0	0	0	0	0	1	0	1	1	0	1	0	0	0
TOTAL CURABLE	35	45	80	10	13	23	2	4	6	11	6	17	5	12	17	7	10	17
Surgical Complications	1	1	2	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1
Trachoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phthisis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other corneal scar	4	2	6	0	1	1	1	0	1	2	0	2	1	0	1	0	1	1
Onchocerciasis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL PREVENTABLE	5	3	8	1	1	2	1	0	1	2	0	2	1	0	1	0	2	2
TOTAL AVOIDABLE	40	48	88	11	14	25	3	4	7	13	6	19	6	12	18	7	12	19
TOTAL COMBINED POSTERIOR SEGMENT	11	7	18	2	1	3	3	3	6	1	0	1	3	1	4	2	2	4
Total Cases	51	55	106	13	15	28	6	7	13	14	6	20	9	13	22	9	14	23

Curable disorders: Refractive error, untreated cataract, and uncorrected aphakia. Preventable disorders: Surgical complications, trachoma, phthisis, corneal scarring, and onchocerciasis. Avoidable: all curable and preventable disorders. Combined posterior segment: all disorders not principally related to the anterior segment of the eye: glaucoma, diabetic retinopathy, age-related macular degeneration, globe abnormalities, and other posterior segment or central nervous system disorders.

Table 7: Principal causes of bilateral severe visual impairment, VA<6/60, by sex per state.

State	All States			Kassala			Northern			Northern Kordofan			Sennar			White Nile		
Sex	Male	Female	Totals	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Cause	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Refractive Error	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cataract, Untreated	31	24	55	9	5	14	5	2	7	6	2	8	6	6	12	5	9	14
Aphakia, uncorrected	1	3	4	0	2	2	0	1	1	0	0	0	0	0	0	1	0	1
TOTAL CURABLE	32	27	59	9	7	16	5	3	8	6	2	8	6	6	12	6	9	15
Surgical Complications	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Trachoma	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Phthisis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other corneal scar	1	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Onchocerciasis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL PREVENTABLE	3	0	3	1	0	1	0	0	0	0	0	0	0	0	0	2	0	2
TOTAL AVOIDABLE	35	27	62	10	7	17	5	3	8	6	2	8	6	6	12	8	9	17
TOTAL COMBINED POSTERIOR SEGMENT	10	3	13	1	0	1	3	0	3	1	1	2	0	1	1	5	1	6
Total Cases	45	30	75	11	7	18	8	3	11	7	3	10	6	7	13	13	10	23

Curable disorders: Refractive error, untreated cataract, and uncorrected aphakia. Preventable disorders: Surgical complications, trachoma, phthisis, corneal scarring, and onchocerciasis. Avoidable: all curable and preventable disorders. Combined posterior segment: all disorders not principally related to the anterior segment of the eye: glaucoma, diabetic retinopathy, age-related macular degeneration, globe abnormalities, and other posterior segment or central nervous system disorders.

Table 8: Principal causes of bilateral visual impairment, VA<6/18, by sex per state.

State	All States			Kassala			Northern			Northern Kordofan			Sennar			White Nile		
Sex	Male	Female	Totals	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Cause	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Refractive Error	3	4	7	3	3	6	1	0	1	0	0	0	0	0	0	0	0	0
Cataract, Untreated	156	130	286	38	27	65	19	22	41	27	26	53	34	22	56	38	33	71
Aphakia, uncorrected	10	8	18	4	4	8	0	1	1	1	1	2	2	1	3	3	1	4
TOTAL CURABLE	169	142	311	45	34	79	20	23	43	28	27	55	36	23	59	41	34	75
Surgical Complications	7	1	8	1	0	1	4	1	5	1	0	1	0	0	0	1	0	1
Trachoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phthisis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other corneal scar	2	4	6	1	2	3	1	2	3	0	0	0	0	0	0	0	0	0
Onchocerciasis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL PREVENTABLE	9	5	14	2	2	4	5	3	8	1	0	1	0	0	0	1	0	1
TOTAL AVOIDABLE	178	147	325	47	36	83	25	26	51	29	27	56	36	23	59	42	34	76
TOTAL COMBINED POSTERIOR SEGMENT	23	21	44	3	4	7	5	7	12	4	3	7	0	4	4	11	3	14
Total Cases	201	168	369	50	40	90	30	33	63	33	30	63	36	27	63	53	37	90

Curable disorders: Refractive error, untreated cataract, and uncorrected aphakia. Preventable disorders: Surgical complications, trachoma, phthisis, corneal scarring, and onchocerciasis. Avoidable: all curable and preventable disorders. Combined posterior segment: all disorders not principally related to the anterior segment of the eye: glaucoma, diabetic retinopathy, age-related macular degeneration, globe abnormalities, and other posterior segment or central nervous system disorders.

Table 9: Prevalence of bilateral cataract causing blindness, SVI, and VI, by sex per state.

State	All States			Kassala						Northern						Northern Kordofan						Sennar						White Nile					
Sex	Totals			Male		Female		Total		Male		Female		Total		Male		Female		Total		Male		Female		Total		Male		Female		Total	
Cause	Population	n	*Prev. per 100 people*	n	*Prev.*	n	*Prev.*	n	*Prev.*	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.	n	Prev.
Cataract Blindness (VA<3/60) with pinhole correction																																	
Bilateral Cataract	106	60	*56.60*	7	*6.60*	8	*7.55*	15	*14.15*	2	1.89	3	2.83	5	4.72	7	6.60	6	5.66	13	12.26	4	3.77	9	8.49	13	12.26	7	6.60	7	6.60	14	13.21
Cataract with Severe Visual Impairment (VA<6/60) with pinhole correction																																	
Bilateral Cataract	75	50	*66.67*	9	*12.00*	4	*5.33*	13	*17.33*	4	5.33	2	2.67	6	8.00	6	8.00	1	1.33	7	9.33	6	8.00	5	6.67	11	14.67	4	5.33	9	12.00	13	17.33
Cataract with Visual Impairment (VA<6/18) with pinhole correction																																	
Bilateral Cataract	369	259	*70.19*	35	*9.49*	24	*6.50*	59	*15.99*	16	4.34	18	4.88	34	9.21	22	5.96	25	6.78	47	12.74	33	8.94	21	5.69	54	14.63	37	10.03	28	7.59	65	17.62

Population: the number of individuals in entire study with bilateral vision loss from all causes at particular VA.
n: the number of bilateral cataract-related vision loss.
Prev.: the prevalence per 100 people per population in study.

Table 10: All reported barriers to cataract surgery regardless of level of vision loss, by sex per state.

State			Kassala			Northern			Northern Kordofan			Sennar			White Nile		
Sex	Total in Study		Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Barrier	n	%	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Cannot Afford Operation	977	39.14	139	124	263	24	35	59	103	82	185	105	106	211	122	137	259
Told to Wait for Cataract Maturity	439	17.59	38	45	83	35	44	79	41	31	72	59	52	111	47	47	94
No knowledge of treatment or how to get surgery	353	14.14	46	51	97	26	36	62	41	43	84	32	34	66	18	26	44
Combined No Need Felt	200	8.01	32	21	53	19	18	37	18	24	42	14	26	40	15	13	28
No Surgical Services	158	6.33	19	36	55	4	9	13	9	13	22	13	15	28	16	24	40
Other Disease Contra-Indicating Operation	143	5.73	12	11	23	22	18	40	17	10	27	21	6	27	18	8	26
Combined 'Beliefs'	123	4.93	21	12	33	11	13	24	11	9	20	12	10	22	9	15	24
No One to Accompany	57	2.28	6	11	17	1	4	5	18	14	32	0	1	1	2	0	2
No Time	46	1.84	8	8	16	2	2	4	10	1	11	7	2	9	3	3	6
All Barriers	2496	100.00	321	319	640	144	179	323	268	227	495	263	252	515	250	273	523

No knowledge of treatment or how to get surgery: combined unawareness of treatment and no knowledge of how to get surgery. Combined No need felt: combined no need felt due to either old age or adequacy of one eye's vision. Combined 'Beliefs:' combined destiny/god's will and fears of operation or losing sight.

Table 11: Barriers to cataract surgery reported by cases of bilateral vision loss to cataract, per state.

State	All States						Kassala			Northern			North Kordofan			Sennar			White Nile		
Level of Vision Loss	Blind		SVI		VI		Blind	SVI	VI	Blind	SVI	VI	Blind	SVI	VI	Blind	SVI	VI	Blind	SVI	VI
Barrier	n	%	n	%	n	%	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Cannot Afford Operation	37	47.44%	27	42.86%	107	35.20%	12	8	26	1	2	6	7	4	11	10	5	30	7	8	34
No Surgical Services	12	15.38%	8	12.70%	30	9.87%	2	3	7	1	0	2	4	0	5	2	0	6	3	5	10
No knowledge of treatment or how to get surgery	12	15.38%	12	19.05%	46	15.13%	2	6	14	3	2	5	2	1	15	1	3	9	4	0	3
Told to Wait for Cataract Maturity	7	8.97%	7	11.11%	71	23.36%	0	0	14	0	1	11	1	0	12	3	5	14	3	1	20
Combined No Need Felt	6	7.69%	5	7.94%	16	5.26%	3	1	4	0	2	4	1	1	5	1	1	2	1	0	1
Combined 'Beliefs'	2	2.56%	1	1.59%	19	6.25%	1	0	5	0	0	5	1	0	2	0	0	5	0	1	2
Other Disease Contra-Indicating Operation	1	1.28%	0	0.00%	4	1.32%	0	0	1	0	0	1	1	0	1	0	0	1	0	0	0
No Time	1	1.28%	1	1.59%	3	0.99%	0	0	1	0	0	1	1	0	0	0	0	1	0	1	0
No One to Accompany	0	0.00%	2	3.17%	8	2.63%	0	0	2	0	0	1	0	2	5	0	0	0	0	0	0
All Barriers	78	100.00%	63	100.00%	304	100.00%	20	18	74	5	7	36	18	8	56	17	14	68	18	16	70

Blind: VA<3/60; SVI: Severely visually impaired, VA<6/60; VI: Visually impaired, VA<6/18

Table 12: Cataract surgical coverage (cataract surgeries by person compared to the number of persons who require cataract surgery) by sex per state.

Sex / State	Kassala	Northern	Northern Kordofan	Sennar	White Nile
Total	63.90%	77.83%	63.59%	64.86%	66.91%
Males	59.84%	76.60%	65.00%	61.95%	68.42%
Females	68.42%	78.90%	61.90%	67.89%	65.08%

Cataract Surgical Coverage Persons (%)= [(x+y)/(x+y+z)]*100, where x was the number of people with one operated and one visually impaired eye; y was the number of people with bilateral aphakia or pseudophakia; and z was the number of bilaterally visually impaired by cataract (for a specific level of vision)

Table 13: Places of reported cataract surgeries, by sex per state.

State	All States			Kassala			Northern State			North Kordofan			Sennar			White Nile		
Sex	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Place	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Government Hospital	210	218	428	44	54	98	39	34	73	46	39	85	36	45	81	45	46	91
Voluntary/Charitable Hospital	69	65	134	3	3	6	18	18	36	18	8	26	8	5	13	22	31	53
Private Hospital	84	82	166	9	12	21	24	38	62	9	3	12	12	14	26	30	15	45
Eye Camp/Improvised Setting	80	74	154	24	27	51	9	7	16	20	11	31	18	14	32	9	15	24
Traditional Setting	22	19	41	10	7	17	1	0	1	4	6	10	4	3	7	3	3	6
All Places of Operation	465	458	923	90	103	193	91	97	188	97	67	164	78	81	159	109	110	219

Table 14: Types of cataract surgery performed, by sex per state.

State	All States			Kassala			Northern State			North Kordofan			Sennar			White Nile		
Sex	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Type	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Non-IOL	101	87	188	29	20	49	17	12	29	25	17	42	4	13	17	26	25	51
IOL Implant	353	361	714	58	80	138	74	85	159	70	46	116	70	67	137	81	83	164
Couching	11	10	21	3	3	6	0	0	0	2	4	6	4	1	5	2	2	4
All Types of Surgery	465	458	923	90	103	193	91	97	188	97	67	164	78	81	159	109	110	219

Table 15: Types of cataract surgery performed by place of operation, per state.

Place	All Places of Operation			Government Hospital			Voluntary / Charitable Hospital			Private Hospital			Eye Camp/Improvised Setting			Traditional Setting		
Surgery Type	Non-IOL	IOL Implant	Couching	Non-IOL	IOL Implant	Couching	Non-IOL	IOL Implant	Couching	Non-IOL	IOL Implant	Couching	Non-IOL	IOL Implant	Couching	Non-IOL	IOL Implant	Couching
State	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Kassala	49	138	6	24	74	0	0	6	0	2	19	0	12	39	0	11	0	6
Northern	29	159	0	18	55	0	2	34	0	5	57	0	3	13	0	1	0	0
Norht Kordofan	42	116	6	32	53	0	2	24	0	1	11	0	3	28	0	4	0	6
Sennar	17	137	5	11	70	0	0	13	0	2	24	0	2	30	0	2	0	5
White Nile	51	164	4	31	60	0	7	46	0	8	37	0	3	21	0	2	0	4
Total	188	714	21	116	312	0	11	123	0	18	148	0	23	131	0	20	0	21

Table 16: Average satisfaction score after cataract surgery, by type per state.

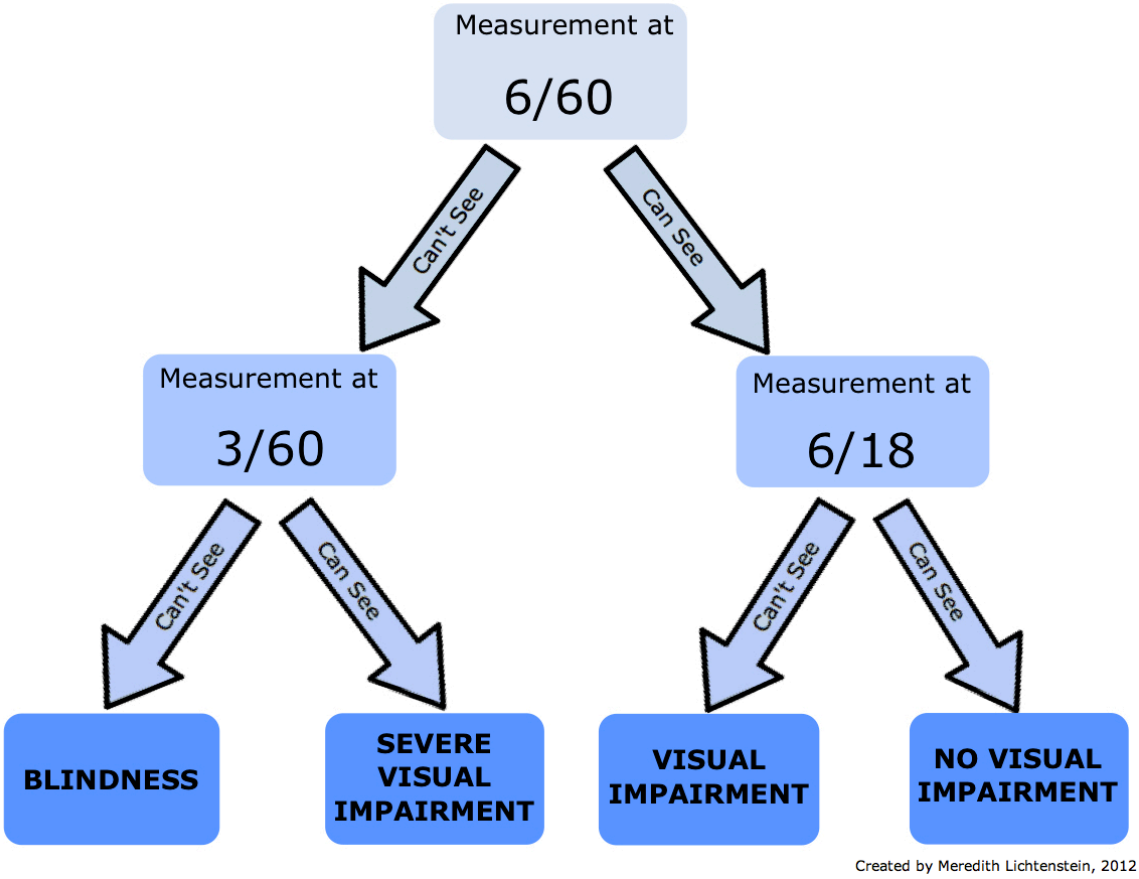
Surgery Type	All Types		Non-IOL		IOL-Implant		Couching		P-Values		
State	n	Average Satisfaction Score	n	Average Satisfaction Score	n	Average Satisfaction Score	n	Average Satisfaction Score	Comparison Between Non-IOL and IOL Implant	Comparison Between Non-IOL and Couching	Comparison Between IOL and Couching
Kassala	193	2.17	49	2.61	138	1.93	6	4	0.0001	0.0019	< 0.0000
Northern	188	2.07	29	2.72	159	1.95	0	N/A	0.0061	N/A	N/A
Norht Kordofan	164	2.2	42	2.45	116	2.05	6	3.33	0.0294	0.0003	< 0.0000
Sennar	159	2.11	17	2.94	137	1.95	5	3.6	0.0016	0.3043	0.0107
White Nile	219	2.13	51	2.71	164	1.88	4	5	< 0.0000	< 0.0000	< 0.0000
Total	923	2.14	188	2.65	714	1.95	21	3.9	< 0.0000	< 0.0000	< 0.0000

Satisfaction score: subjects rated personal satisfaction with surgery on a numeric scale, 1=very satisfied, 2=partially satisfied, 3=indifferent, 4=partially dissatisfied, 5=very dissatisfied

Table 17: Cost of cataract surgery by place of operation, per state.

Place of Operation	All Places			Government Hospital			Volunteer/Charitable Hospital			Private Hospital			Eye Camp/Improvised Setting			Traditional Setting		
Cost	Totally Free	Partially Free	Paid-in-Full	Totally Free	Partially Free	Paid-in-Full	Totally Free	Partially Free	Paid-in-Full	Totally Free	Partially Free	Paid-in-Full	Totally Free	Partially Free	Paid-in-Full	Totally Free	Partially Free	Paid-in-Full
State	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Kassala	65	20	108	15	13	70	1	3	2	2	1	18	45	1	5	2	2	13
Northern	25	16	147	7	6	60	2	7	27	1	2	59	15	1	0	0	0	1
Norht Kordofan	45	3	116	10	1	74	3	2	21	3	0	9	29	0	2	0	0	10
Sennar	32	13	114	4	9	68	0	0	13	0	1	25	28	2	2	0	1	6
White Nile	39	24	156	10	7	74	3	15	35	0	2	43	24	0	0	2	0	4
Total	206	76	641	46	36	346	9	27	98	6	6	154	141	4	9	4	3	34

APPENDIX A – Flow Chart of Visual Acuity Testing During RAAB Survey



APPENDIX B – IRB Letter of Determination

EMORY UNIVERSITY | Institutional Review Board

February 16, 2012

Meredith Lichtenstein
Rollins School of Public Health
Atlanta, GA 30322

RE: Determination: No IRB Review Required
Title: *Cataract Surgery in the Sudan – MPH Thesis Project*

Dear Ms. Lichtenstein:

Thank you for requesting a determination from our office about the above-referenced project. Based on our review of the materials you provided, we have determined that it does not require IRB review because it does not meet the definition of research with "human subjects" or the definition of "clinical investigation" as set forth in Emory policies and procedures and federal rules, if applicable. Specifically, in this project, you will analyze survey results from a survey conducted by another entity in Sudan, and the data you analyze will contain no HIPAA identifiers other than an ID code number for which you and your collaborator will not have access to the key to link that code to any identifiers.

This determination could be affected by substantive changes in the study design. If the project changes in any substantive way, please contact our office for clarification.

Thank you for consulting the IRB.

Sincerely,

Rebecca Rousselle

Rebecca Rousselle, CIP
Assistant Director

Emory University
1599 Clifton Road, 5th Floor - Atlanta, Georgia 30322
Tel: 404.712.0720 - Fax: 404.727.1358 - Email: irb@emory.edu - Web: http://www.irb.emory.edu