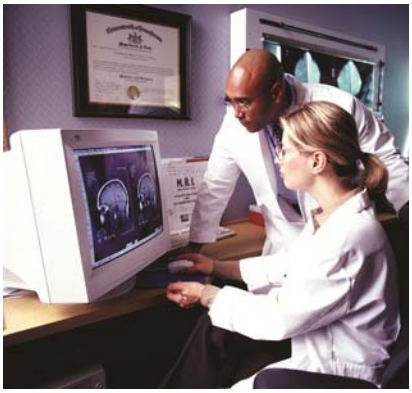
The LEWIN GROUP®



Cost-Benefit Analysis of Corneal Transplant

Prepared for:

EYE BANK ASSOCIATION of AMERICA

September, 2013

Cost-Benefit Analysis of Corneal Transplant

Final Report

Prepared for:

Eye Bank Association of America

Submitted by:

The Lewin Group, Inc.

September 9, 2013

Table of Contents

Introduction

More than 46,000 corneal transplants were performed in 2011.[1] A sight-saving surgery, corneal transplantation restores sight for patients who suffer from vision loss due to corneal damage or disease. Many diseases could affect the cornea, including eye and cornea infections, Fuchs' and other corneal dystrophies, herpes zoster (shingles), iridocorneal endothelial syndrome, and keratoconus. Corneal diseases primarily affect older people.[2] Surgery complications such as pseudophakic bullous keratopathy, and traumatic injury, could also damage the cornea and necessitate a corneal transplant procedure.[3]

Corneal tissues are obtained by eye banks from deceased individuals who arranged for donation prior to their death or whose families gave permission. Many eye banks are supported by eye bank ambassadors, volunteer groups composed of corneal transplant recipients and family members of eye tissue donors. The Eye Bank Association of America (EBAA) was founded in 1961 to lead the tissue transplantation community in ensuring continued corneal transplantation successes through technique development and research. According to EBAA, since 1991, about 763,000 transplants have been performed in the U.S. and about 255,000 internationally.

During corneal transplant surgery, the scarred or damaged cornea is removed and replaced by a human donor cornea called a graft. The major types of corneal transplant procedures are penetrating keratoplasty where a damaged or diseased cornea is replaced in its entirety with a donor graft; anterior lamellar keratoplasty where only the front part of the corneal thickness is transplanted; and endothelial keratoplasty where only the back part is transplanted. Some variations of endothelial keratoplasty include deep lamellar endothelial keratoplasty and Descemet's stripping endothelial keratoplasty.

As reported by the 2012 Eye Banking Statistical Report, between 2008 and 2012, the total number of corneal grafts increased by 31% from 52,487 to 68,681.[4] The demand for corneal tissue is on the rise due to population aging and an increasing trend in corneal transplants, particularly the endothelial keratoplasty procedure. [4] The cost of corneal transplantation has also increased over time. Between 2005 and 2011, the average estimated charges billed for the first year of a corneal transplant increased by 28%.[1, 5] The cost of corneal tissue processing is increasing due to increases in regulatory requirements and in advanced procedures calling for more complex tissue preparation methods. Together, the costs of corneal tissue; facility, physician and anesthesia services; and of pre- and post-operative care represent a significant burden to public and private payers, and to the patients' families. While numerous studies have reported increased visual function and improved quality of life following a corneal transplant procedure, there are limited data on the economic impact of corneal transplants.[1, 6-8]

The purpose of this study is to examine the costs and benefits associated with corneal transplantation. We include medical costs associated with the procedure itself and with

pre- and post-operative care in this estimate of the cost of corneal transplantation. The benefits of corneal transplantation are considered under a hypothetical scenario where the study cohort did not receive a transplant and stayed in the continued state of severe vision impairment or blindness for the remainder of their lives. We discuss lifetime costs attributed to vision loss, including medical costs, costs of long term care and costs due to lost productivity.

Because there is no single, longitudinal source of data with which to conduct this study and achieve its objectives, we use a combination of medical claims data and evidence from the literature to estimate the costs and benefits of corneal transplantation. To capture benefits of corneal transplantation, we use data from the literature combined with original analysis using data sources such as the U.S. Census Population Projections and the Current Population Survey (CPS) to calculate the direct medical costs and indirect costs associated with vision loss. Overall savings from corneal transplantation are derived from comparing the cost of transplantation and savings from avoidance of vision impairment and blindness. All cost estimates are in 2013 dollars.[1]

[1] The study was reviewed by the New England Institutional Review Board and granted exemption from a full review.

Cost of Corneal Transplant

A. Study cohort

To estimate the direct medical cost associated with corneal transplantation, we first calculate the probability of a person receiving a corneal transplant by type of procedure, patient age and sex. We cluster the study cohort into four age groups – age 0 to 17, age 18 to 39, age 40 to 64, and age 65 and above. To estimate age-specific probability of corneal transplant for the three younger age groups, we use the OptumInsight de-identified Normative Health Information (dNHI) database, one of the nation's largest healthcare administrative databases that contain historical medical and pharmacy claims for over 25 million covered lives in each year. The underlying population is geographically diverse and comparable to the U.S. population in terms of age and sex for the population under age 65. To estimate the probability of receiving a corneal transplant among the Medicare eligible population, we used the Centers for Medicare and Medicaid Services (CMS) Standard Analytical Files (SAF) Medicare 5% sample claims data for beneficiaries covered by both Part A and Part B on a fee-for-service basis.

We focus on three major types of corneal transplant procedures. Each procedure is identified using ICD-9 and CPT-4 procedure codes which are shown in Appendix Table 1. We consider the following procedure types

1. Penetrating keratoplasty (PK),
2. Lamellar keratoplasty (ALK), and
3. Endothelial keratoplasty (EK), includes descemet-stripping endothelial keratoplasty (DSEK) or descemets membrane endothelial keratoplasty (DMEK); descemet stripping automated endothelial keratoplasty (DSAEK); and femtosecond laser-assisted descemet-stripping endothelial keratoplasty (FS-DSEK).

Using logistic regression with the receipt of a procedure (PK, EK, or ALK) as a dichotomous dependent variable and individual age and sex as explanatory variables, we predict the probability of receiving a corneal transplant by age group and sex. The predicted probabilities are then combined with Census projected 2011 U.S. population by age group and sex to estimate the number of people receiving each procedure in each age group and sex stratum.[9] Based on this calculation, in 2011, 39,148 corneal transplant procedures are estimated to have been performed. We adjust our 2011 estimate of 39,148 corneal transplants upward to match the EBAA estimate by proportionally allocating the difference of 7,048 procedures to each age group, sex and procedure-specific number of transplants. Then we apply the rate of increase in population between 2011 and 2013, to the adjusted number of transplants in 2011 to estimate the number of transplants in 2013. Exhibit 1 shows the estimated number of corneal transplant procedures by age group and type of procedure.

47,361 people are estimated to receive a corneal transplant in 2013 while 75% of them (over 35,000 procedures) are estimated to be performed on patients age 65 and older. PK is the most commonly performed procedure among those under the age of 65 while EK is the most common procedure for those aged 65 and older. ALK is the least common procedure regardless of the age of the patient, which is consistent with the pattern in types of keratoplasty procedures in the 2012 Eye Banking Statistical Report.[4]

Exhibit 1: Total number of corneal transplant procedures in 2013 by recipient age (adjusted)*

Age	PK #	EK #	ALK #	Total	Percentage of Total
0-17	317	45	0	362	1%
18-39	2,287	144	36	2,466	5%
40-64	4,771	691	3,663	9,125	19%
65+	11,816	22,623	969	35,408	75%
Total	19,190	23,503	4,668	47,361	100%

Source: Data for population under age 65 is obtained from OptumInsight dNHI database and for population age 65 or older from Medicare 5% SAF.
*Sum of the numbers may not equal to the total due to rounding.

B. Cost of corneal transplant procedures

The main sources of data for this analysis, as described earlier, are the dNHI data for patients younger than age 65, and Medicare SAF for patients age 65 and older. In our analysis of costs for corneal transplant procedures, we include tissue fee, facility cost, surgeon fee, and anesthesia costs. Pre- and post-operative costs associated with each type of procedure are also examined. We analyze the medical claims data to estimate cost of corneal transplants for each of the three major types of keratoplasty procedures –PK, EK, and ALK.

Cost of the tissue fee is handled differently by Medicare and private plans. While Medicare reimburses facilities for the tissue fee based on the invoice fee charged by the eye bank in addition to the procedure facility fee, the majority of the procedures identified through the dNHI data involve combined reimbursement for tissue and facility costs. In such cases, it is not feasible to separate the cost of corneal tissue from the facility fee. In addition to costs for corneal tissue transplant procedures, other analyzed cost components of corneal transplantation include cost of pre-operative care, including primarily the pre-surgery doctor consultation and laboratory examinations; and cost of post-operative care, including outpatient follow-up visits, exams, medications, and visual rehabilitation. Cost of both pre- and post-operative cares are important variables in accurately calculating the total costs associated with corneal transplantation.

We include pre-operative care during the three months prior to the surgery and post-operative care during the twelve months following the procedure. ICD-9 diagnosis codes associated with relevant pre- and post-operative procedures are listed and described in

Appendix Table 2. Since we use the latest Medicare claims data available at the time of this report, which is from year 2011, not every patient in the data has twelve months of claims information available following the surgery. We therefore calculate the pre- and post-operative costs during the three- and twelve-months period based on the average monthly cost calculated for each patient and each cost component. We analyze the private insurance claims data in a similar way to be consistent with the Medicare component of the analysis. Exhibit 2 shows the average cost of procedures by age-group and types of services and Appendix Table 3 shows the average and median costs by type of service analyzed for each corneal transplant procedure and cost component. In order to be consistent in the methodology of the remainder of the study, we consider the average cost of transplant instead of the median cost in all cost calculations. Although the cost of post-operation medications could vary greatly based on drug characteristics including whether the medication is brand or generic, based on medical and corneal transplant expert opinion, we estimate a $200 per capita cost of medications during the year after the transplant. This includes one bottle of antibiotic drops and five bottles of steroid drops. Also a small percentage of patients require pressure lowering medications. Our estimated average cost of $16,500 across all age groups and procedures is lower than the Milliman reported $24,400, since the later uses charge data instead of cost and only from one large health system.[1]

Exhibit 2: Average cost of corneal transplant procedures*

Procedure Cost Component	Under 65			65 and older		
	Penetrating	Endothelial	Lamellar	Penetrating	Endothelial	Lamellar
Anesthesia	$1,085	$1,024	$1,309	$236	$236	$252
Physician	$1,634	$1,782	$1,563	$3,185	$4,072	$2,651
Tissue				$2,088	$2,449	$1,949
Facility**	$5,196	$4,517	$3,889	$3,031	$3,230	$2,873
Pre-op	$1,284	$1,655	$770	$1,040	$1,119	$509
Post-op	$9,509	$11,774	$3,332	$7,004	$5,037	$7,973
Medications***	$200	$200	$200	$200	$200	$200
Total	$18,907	$20,953	$11,062	$16,783	$16,343	$16,408

Source: Data for population under age 65 is obtained from OptumInsight dNHI database and for population age 65 or older from Medicare 5% SAF.
* Sum of the numbers may not equal to the total due to rounding
**Includes tissue fee for population under age 65
***Based on medical expert opinion

Although we consider it important to categorize the transplant procedures by care setting (hospital, ambulatory surgery centers, etc.), our exploratory analysis show that only 3% of all corneal transplant procedures take place in an inpatient setting. This is consistent with the Milliman report which states that outpatient corneal transplants represent well over 99% of total corneal transplants performed in 2008 and just under 99% of all billed charges.[1] Due to the small sample size of the procedures performed within a hospital, we

report the estimated average cost by procedure and cost component for all places of service combined.

To estimate the total cost of a corneal transplant for a hypothetical patient in our study cohort in each age group, we combine the total cost for each type of transplant procedure (EK, PK, and ALK) with the number of procedures performed in each age-sex group to estimate the weighted average per-person medical cost of corneal transplant. Cost of a corneal transplant for each age group is shown in Exhibit 3.

Exhibit 3: Cost of corneal transplant per-person (all procedures combined)

Age Group	Cost of Transplant
0-17	$19,200
18-39	$18,900
40-64	$15,900
65+	$16,500
Average	$16,500

Source: Data for population under age 65 is obtained from OptumInsight dNHI database and for population age 65 or older from Medicare 5% SAF.

Cost of vision loss and potential savings from corneal transplantation

Successful corneal transplants avoid the cost that would have occurred in the absence of this sight-saving surgery. Therefore, we regard the cost of blindness, which could have been avoided by the transplant, as the economic benefit of corneal transplant. Failure to obtain a corneal transplant, when medically necessary to restore sight, can lead to a drastic deterioration of vision and possibly to blindness. Although intuitive, it is well supported by literature that low vision is associated with increased healthcare expenditure and loss of productivity.[10-12] Additionally, impaired vision reduces functionality and adversely affects quality of life.[13, 14] In this study, we focus on the direct and indirect economic benefits of corneal transplants.

Our analysis considers direct medical and indirect costs of blindness from a societal perspective. We consider medical and long term care costs attributed to diagnosed blindness, in the direct medical cost estimates. For indirect costs, we focus on the cost of lost productivity as measured by to the average reduction in median income of the patient and the cost of lost productivity for the caregiver(s) due to informal care provided to the patient. In our analysis we only focus on tangible costs incurred or forgone; intangible costs due to reduced quality of life are not considered.

Cost of Vision Problems: The Economic Burden of Vision Loss and Eye Disorders in the United States, a comprehensive report recently published by the Prevent Blindness America and National Opinion Research Center, estimates that the total medical cost for blindness and low vision in the U.S. in 2013 is $3,760 million.[15] Total productivity loss to the patients is estimated to be $48.4 billion in 2013.[15] This study is an update of the landmark 2007 report which has been regarded as the primary estimate of economic burden of eye and vision problems since its publication. In our analysis we leverage the direct medical and indirect costs associated with blindness as estimated by the 2013 update, and combine its results with data from other sources, to estimate the total cost of blindness.

One point to be noted is that by leveraging this comprehensive and most recent report, we may have underestimated the true lifetime cost of a newly blind patient as determined by what would have happened to individuals in our hypothetical study cohort over time, from initial loss of sight. This is because *Cost of Vision Problems* estimates the cost attributed to low vision and blindness using a prevalence approach. Therefore study subjects who may or may not be newly diagnosed are included in the sample and the estimated average cost per person is the average cost of previously and newly diagnosed patients. The implication of this methodology is that, by using the average per-person medical cost from *Cost of Vision Problems* as the average cost of the first year of onset of blindness, and by using this first-year cost to project lifetime cost, our estimates of total lifetime cost attributed to blindness may be conservative, because newly diagnosed patients incur higher costs in their first year, and this prevalence-based study pool contains both newly and previously diagnosed patients. However, such estimates

could provide a benchmark by which the long-term economic impact of blindness can be better understood.

Although the *Cost of Vision Problems* study reports costs attributed to both visual impairment and blindness, we only consider the costs attributed to blindness, where it is possible to separate the two sources of costs. Visual acuity of 20/40 to 20/200 is categorized as visual impairment by the study. Since corneal transplant is not a medical necessity for the majority of the visually impaired, as defined by *Cost of Vision Problems*, to report conservative estimates of benefits of corneal transplant, we consider only the costs associated with blindness.

Furthermore, *Cost of Vision Problems* reports the total prevalent population with vision loss in 2010 using prevalence rates by age group estimated from the 2005-2008 National Health and Nutrition Examination Survey (NHANES). We apply the prevalence rate with the 2013 U.S Census projected population to estimate the prevalence of vision loss in 2013.

In estimating the economic impact of blindness to the society for the remainder of a patient's life, we consider the average life expectancy published by Centers for Disease Control and Prevention (CDC).[16] In estimating the loss of productivity due to reduced income, we consider 65 as the age of retirement when the hypothetical person in the study stops incurring indirect costs due to lost productivity. Since we report lost productivity, both due to reduced earnings and informal care, in real dollars in the study base year 2013, we do not account for annual inflation. Since we report cost of long-term care services attributed to low vision in real dollars as well, we reduce the annual rate of increase in nursing home costs by the amount of general inflation. Due to unavailability of predicted long-term care services inflation data, we use the most recent annual rate of increase in Nursing Home and Adult Day Services Consumer Price Index (CPI) (3.52%), which we reduce by the 10-year predicted rate of increase in general CPI of 2.44% by Congressional Budget Office (CBO) to obtain a net long-term care CPI of 1.08%.[17, 18] In order to estimate the NPV of all future costs, we use a 3% discount rate as recommended by the literature.[19]

A. Direct costs associated with blindness

Medical cost

The *Cost of Vision Problems* study estimates a per-person medical cost of $6,680 for those diagnosed with blindness and low vision in a year. Using the Medical Expenditure Panel Survey (MEPS) data and a two-part generalized linear model, it estimates the overall medical cost attributable to blindness and low vision using a "top-down" econometric approach whereby the incremental costs attributed to blindness and low vision are estimated while controlling for socio-demographic conditions and comorbidities between the study group and the comparison group. This approach allows estimation of ancillary costs beyond those directly related to eye care services.[15] A major limitation of utilizing

MEPS to estimate medical cost is that diagnoses are reported only at the 3-digit ICD-9 level, which means that it is impossible to identify visual impairment from blindness which requires analysis at the 5-digit ICD-9 level. Therefore, for medical cost of blindness, The *Cost of Vision Problems* study did not separate blindness and low vision. Exhibit 4 shows the per-person medical cost attributed to blindness and low vision and the cost of vision correction.

Exhibit 4: Per-person medical cost of blindness and low vision

Age Group	Attributable Medical Cost
0-17	$1,490
18-39	$2,820
40-64	$5,870
65+	$10,020

Source: Table 6.2 Per-person annual medical costs by disorder, Cost of Vision Problems: The Economic Burden of Vision Loss and Eye Disorders in the United States, 2013

We use the annual medical costs attributed to blindness and low vision as shown in Exhibit 4 as the direct cost incurred during the first year of blindness and low vision. Cost attributed to blindness includes costs due to hospital inpatient, dental care, outpatient, office-based provider, prescribed medicines, emergency room, home health care, and medical equipment and ancillary services. Older patients incur higher costs attributed to blindness because healthcare expenditure increases with age. According to a CMS report, per-person healthcare spending for the 65 and older population is about 5.6 times higher than the spending of a child and about 3.3 times the spending of those between ages 19 and 64.[20] Since the literature shows that the medical cost of those with blindness and low vision does not differ substantially from the cost of those without,[21] in the follow-up period beyond the first year, we assume that the medical cost of the people diagnosed with blindness and low vision is similar to that of people without the diagnosis. Therefore, the attributed medical cost in the first year is assumed to be equal to the lifetime medical cost attributed to blindness and low vision.

Long term care

Leveraging the data reported in *Cost of Vision Problems*, we estimate the cost of long term care resources attributed to blindness for age 65 and older. We include nursing home and skilled nursing facility (SNF) care as long term care services. The former generally refers to long term stays with costs paid by the patient or Medicaid. SNF stays are generally shorter in duration and are covered by Medicare for the age 65 and older population.[15] *Cost of Vision Problems* regards long term care costs attributed to blindness as indirect costs. However, as long term care costs refer to utilization of health resources directly as a result of the condition being studied, we consider them as a component of direct medical costs.

Cost of Vision Problems estimates total cost of nursing home care attributed to blindness to be $16.8 billion in 2013 for the entire prevalent population with blindness. It compares the relative difference in prevalence of blindness among the nursing home population, estimated from 2004 National Nursing Home Survey, with the prevalence among the age-matched general population. The difference between the two prevalence rates is combined with the population with blindness to estimate the size of the population using nursing home services because of blindness. Combining this size estimate with the average duration of nursing home stay per year and the average cost of nursing home care from the 2011 Genworth Financial Cost of Care Survey, *Cost of Vision Problems* estimates the total cost of nursing home care attributed to blindness for age 65 and older as $16.8 billion.[15] We use the prevalent population in this age group to estimate the per-person cost of nursing home care attributed to blindness. This per-person cost is considered to be the first year cost of nursing home care. Applying remaining life expectancy, net long-term care inflation and discount rate, we estimate the NPV of lifetime cost of nursing home care attributed to blindness.

Cost of Vision Problems only reports nursing home costs for the prevalent population age 65 and above. However, since our study focuses on lifetime costs of attributed nursing home care, we assume that the population that is currently under the age of 65 will incur nursing home costs due to their condition, once they turn 65, and continue to do so for the remainder of their lives. Therefore, we also estimate the NPV of nursing home costs incurred by the three younger age groups, adjusted for life expectancy, net long-term care inflation and discount rate. *Cost of Vision Problems* updates per-person excess Medicare costs for SNFs attributed to blindness estimated by Javitt, et al (2007).[11] The update reflects a total of $3.4 billion SNF cost attributed to blindness. The *Cost of Vision Problems* study reports SNF costs for the entire population of SNF residents. Since Medicare is the primary payer of SNF care, we assume that only those over the age of 65 utilize such care. We use the per-person SNF cost from *Cost of Vision Problems* to estimate the NPV of SNF cost attributed to blindness for those aged 65 and above. Similar to the method used to estimate nursing home costs, we assume that those who are under the age of 65 at present will utilize SNF care once they reach the age of 65.

Since the younger age groups incur long term care costs in the future, the value of those costs in 2013 is lower than the value of the costs incurred by those age 65 and older because the latter incur these costs in the current year. Exhibit 5 shows the attributed average lifetime cost of the nursing home care, SNF care, and combined total long term care.

Exhibit 5: Lifetime long term care cost attributed to blindness (in real dollars)

Age Group	Nursing Home	SNF	Total Long Term Care
0-17	$21,200	$3,900	$25,100
18-39	$31,200	$5,800	$37,000
40-64	$48,100	$8,900	$57,000
65+	$62,600	$11,600	$74,200

Source: Calculated with data from Table 13.1. Nursing Home Cost Estimates and Table 13.2. Medical Skilled Nursing Facility Cost Estimates, *Cost of Vision Problems: The Economic Burden of Vision Loss and Eye Disorders in the United States, 2013*

B. Indirect costs due to vision impairment and blindness

For indirect costs associated with low vision and blindness, we estimate the lifetime cost of productivity loss due to reduced income to individuals with blindness, and to their family members who provide informal care. Similar to our approach in estimating the direct medical cost of low vision and blindness, we leverage the productivity loss estimated by *Cost of Vision Problems* to calculate both first-year and lifetime per-person productivity loss for our hypothetical study cohort. Although *Cost of Vision Problems* also provides indirect cost estimates due to transfer payments, tax losses (deduction) and deadweight loss, we only focus on the part of the indirect cost due to lost productivity to the patient and to the informal family caregiver(s). Transfer payments, which include government assistance programs, are excluded from our analysis as they represent a shift in resources, rather than the use of them or the opportunity cost of forgone productivity.[22] Neither do we consider tax losses nor deadweight loss for similar reasons.

Lost productivity

Cost of Vision Problems reports a $48.4 billion cost of productivity loss due to blindness.[15] This is calculated by primarily using Survey of Income and Program Participation (SIPP). Median income of the people with self-reported blindness is compared with that of the people that do not report any visual impairment for the three younger age groups, adjusting for case mix. The cost of lost productivity is estimated by applying the average reduction in median income associated with blindness to the prevalent population with the condition by age group.[15]

We divide the total lost productivity due to lower wages and reduced workforce participation in 2013 by the prevalence of blindness, both reported by *Cost of Vision Problems*, to estimate the annual per-person productivity loss for age groups 18-39 and 40-64. We consider this annual per-person loss of productivity as the cost due to lost productivity in the first year of blindness. To derive the lifetime productivity loss for these two age groups, as shown in Exhibit 6, we assume that, in the future, they will incur the same level of productivity loss as they do in the base year 2013. This means that we assume no increase in lost productivity over time. Therefore, cost due to lost productivity

incurred by the youngest age group is only very slightly higher, in comparison to the oldest income-earning age group. We calculate the lifetime per-person productivity loss by applying discount rate, in addition to the average number of years until retirement, to the base year cost and thus estimate the NPV of future productivity loss.

Cost of Vision Problems reports the cost of lost productivity for population age 18 and older. However, since we consider lifetime costs, we assume those currently under the age of 18 will incur productivity loss when they reach age 18 until they retire at age 65. To estimate the NPV of this age group's lifetime loss in productivity, we first estimate their loss in productivity at the age of 18. In order to do so, we apply the ratio of mean income for age 18 to the mean income for ages 18 through 39, obtained from Current Population Survey, to the average loss of productivity for age group 18-39.[23] To this productivity loss in the first year (when they become age 18), we apply income growth rate and discount rate to estimate the NPV of lifetime productivity loss attributed to blindness. Exhibit 6 illustrates this lifetime cost of productivity loss.

Exhibit 6: Lifetime cost of lost productivity attributed to blindness (in real dollars)

Age Group	Total Cost of Lost Productivity
0-17	$213,000
18-39	$206,000
40-64	$211,000
65+	$0

Source: Calculated with data from Table 12.1. Productivity Losses, Cost of Vision Problems: The Economic Burden of Vision Loss and Eye Disorders in the United States, 2013

Informal care

Cost of Vision Problems reports a $2.1 billion cost of informal care attributed to blindness.[15] It applies the methodology used by Frick, et al (2007) to estimate the cost of informal care due to low vision for those aged 40 and over.[12] Lafuma, et al (2006) estimated that family members spent 2.0 and 3.3-fold more time caring for individuals with blindness in comparison to those without blindness.[24] *Cost of Vision Problems* combines the ratios reported by Lafuma, et al (2006) to the number of hours spent on childcare by adults estimated from the American Time Use Survey (ATUS) and average hourly wage rate from the Bureau of Labor Statistics (BLS) to obtain the total cost of informal care incurred by adults who care for children with blindness and visual impairment. *Cost of Vision Problems* did not report cost of informal care for the age group of 18-39 and we are unable to identify any recent literature that estimates the cost of informal care for people of this age group. However, it is very likely that blindness in this group results in lost productivity to family members due to informal care. Therefore, for consistency in analysis, we assumed the average of per-person attributed cost of informal care for age groups 0-17 and 40-64 for the age group 18-39.

Similar to the previously mentioned lifetime cost estimation methods, we use age-group specific total cost to estimate the per-person cost of informal care in each age group. Applying average life expectancy and discount rate, we estimate the NPV of the lifetime cost of informal care for a hypothetical person in each age group as shown in Exhibit 7.

Exhibit 7: Lifetime cost of lost productivity due to informal care (in real dollars)

Age Group	Cost of Informal Care
0-17	$20,100
18-39	$13,400
40-64	$7,400
65+	$2,800

Source: Calculated with data from Table 12.2. Productivity Losses Resulting from Informal Care, Cost of Vision Problems: The Economic Burden of Vision Loss and Eye Disorders in the United States, 2013

Costs and benefits associated with corneal transplantation

Corneal transplant has restored vision to hundreds of thousands of people in the U.S. and abroad. The surgical procedure not only restores vision, but also relieves pain and suffering caused by injured and diseased cornea.[25] While the transplant procedure is usually completed within an hour, its positive impact can last a lifetime. In addition to restoration of sight, corneal transplant avoids higher medical cost, opportunity cost of lost productivity, and potential long term care cost, all by eliminating blindness or major visual impairment. Therefore, in this study, using private and Medicare claims data, combined with evidence from the most recent literature, we compare the cost and benefit of corneal transplant. This cost-benefit analysis shows that the net lifetime benefit of the procedure is overwhelmingly greater than the costs of the procedure.

In evaluating costs and benefits of corneal transplant, we examine the medical cost associated with corneal transplantation procedure, which includes the cost of the procedure itself and the cost of care associated with the transplant for three months before and a year after the surgery. We estimate a per-patient average cost of corneal transplant of $16,500; this reflects all related expenses, including corneal tissue, surgeon and anesthesia services, facility costs, pre-operative care, and related services for a year after the transplant.

Because transplantation is the treatment of last resort for those suffering from corneal disease or injury, when evaluating benefits, we consider blindness as the alternative to corneal transplant procedure. Therefore, we use costs of blindness as a proxy for the benefits of corneal transplant, and we assume that the benefits will remain with the patient for the remainder of his or her life. Direct medical costs attributed to blindness include medical care and long term care; these average $77,000 over the course of a person's life.

Indirect benefits include avoided cost of lost productivity incurred by the patients due to their reduced income and by their caregiver(s) due to provision of informal care. We estimate that an average person whose vision has been restored through a corneal transplant procedure will avoid about $214,000 in indirect costs over the course of his or her life. This analysis assumes a uniform retirement at age 65, and thus may understate the true cost of lost productivity. The Census Bureau found that 31% of people aged 65-69, and over 16% of all Americans over 65, continued to work in 2010.

Furthermore, as corneal transplantation avoids cost due to reduced earnings, it also avoids income tax losses to the government and transfer payments funded by tax receipts. We estimate net benefit of corneal transplant by comparing the cost of corneal transplant with the total of direct and indirect costs avoided. Exhibit 8 shows the cost comparison. Since we use real dollars to estimate the NPV of costs that are projected over a lifetime, it is not surprising that those in the age group of 40-64 have the highest net

positive economic impact of corneal transplant. This group incurs the largest per-person loss of productivity due to low vision, because of its higher per-person earned income.

Exhibit 8: Lifetime economic cost-benefit of corneal transplantation

Age Group	N	Medical Cost of Transplant	Benefits: Direct Medical	Benefits: Indirect	Net Lifetime Benefit
0-17	362	$19,200	$27,000	$233,000	$241,000
18-39	2,466	$18,900	$40,000	$219,000	$240,000
40-64	9,125	$15,900	$63,000	$218,000	$265,000
65+	35,408	$16,500	$84,000	$2,800	$71,000
All ages	47,361	$16,500	$77,000	$214,000	$118,000

Source: Medical cost of transplant from analysis of OptumInsight dNHI database and Medicare 5% SAF. Benefits: direct medical from Table 6.5 Per-person annual medical costs by disorder, Table 13.1. Nursing Home Cost Estimates and Table 13.2. Medical Skilled Nursing Facility Cost Estimates, *Cost of Vision Problems: The Economic Burden of Vision Loss and Eye Disorders in the United States, 2013*. Benefits: indirect from Table 12.1. Productivity Losses and Table 12.2. Productivity Losses Resulting from Informal Care, *Cost of Vision Problems: The Economic Burden of Vision Loss and Eye Disorders in the United States, 2013*

Although the net benefit of corneal transplantation for those aged 65 and above is smaller than that in the younger age groups, the benefits associated with providing access to corneal transplant procedures for the oldest age group cannot be ignored. Since 75% of all patients that receive corneal transplant are of age 65 and older and 83% of all Medicare beneficiaries are in this age group, the net direct medical benefit of $67,500 shows the potential for significant savings for Medicare if blindness is avoided.

The literature shows that, based on direct medical costs, eye disorders as a group of conditions are the fifth costliest to the U.S. economy after heart disease, cancer, emotional disorders and pulmonary conditions.[15] While not all eye disorders can be prevented or cured by corneal transplant, the significant net societal benefit of those that can be impacted demonstrates the importance of this sight-saving surgery to the patients, their families, and society. Total societal net benefit of corneal transplant, calculated by combining the number of patients projected to receive corneal transplant procedures in 2013 with the estimated lifetime net benefit of these procedures, is estimated to be nearly $6 billion.

In this report, *Cost-Benefit Analysis of Corneal Transplan*t, we observe that the economic benefit of corneal transplant surpasses the cost by more than five-to-one among the Medicare population and nearly 18-to-one among younger patients. The high net benefit of corneal transplant, demonstrates the importance of this procedure, which not only restores sight for the patient, improves his or her functionality and quality of life, but also provides great economic benefit to the patient, the family, and to society.

Works Cited

1. Bentley, T. Scott and Hanson, Steven G. 2011 US Organ and Tissue Transplant Cost Estimates and Discussion. 4-1-2013. Milliman. Ref Type: Report
2. Sherman W. Reeves et al., "Keratoconus in the Medicare Population," *Cornea* 28, no. 1 (2009): 40.
3. National Eye Institute, "Facts About The Cornea and Corneal Disease," 2013. Available from http://www.nei.nih.gov/health/cornealdisease/.
4. Eye Bank Association of America. Eye Banking Statistical Report. 2013. Washington, DC, Eye Bank Association of America. 7-28-2013. Ref Type: Report
5. Ortner, Nickolas J. 2005 US Organ and Tissue Transplant Cost Estimates and Discussion. 6-1-2005. Milliman. 7-28-2013. Ref Type: Report
6. N. Salam et al., "Quality of Life After Corneal Transplantation: a Retrospective Study]," *Journal fran+°ais d'ophtalmologie* 26, no. 10 (2003): 1016.
7. Flavia Mendes et al., "Assessment of Visual Function After Corneal Transplantation: the Quality of Life and Psychometric Assessment After Corneal Transplantation (Q-PACT) Study," *American journal of ophthalmology* 135, no. 6 (2003): 785-793.
8. Adriano Fasolo et al., "Health Status and Patient Satisfaction After Corneal Graft: Results From the Corneal Transplant Epidemiological Study," *Journal of ophthalmology* 2012 (2012).
9. "Population Projections,", U.S.Census Bureau (2013; <[28] Date).
10. David B. Rein et al., "The Economic Burden of Major Adult Visual Disorders in the United States," *Archives of Ophthalmology* 124, no. 12 (2006): 1754.
11. Jonathan C. Javitt, Zhiyuan Zhou, and Richard J. Willke, "Association Between Vision Loss and Higher Medical Care Costs in Medicare Beneficiaries: Costs Are Greater for Those With Progressive Vision Loss," *Ophthalmology* 114, no. 2 (2007): 238-245.
12. Kevin D. Frick et al., "Economic Impact of Visual Impairment and Blindness in the United States," *Archives of Ophthalmology* 125, no. 4 (2007): 544.
13. Sharon A. Haymes, Alan W. Johnston, and Anthony D. Heyes, "Relationship Between Vision Impairment and Ability to Perform Activities of Daily Living," *Ophthalmic and Physiological Optics* 22, no. 2 (2002): 79-91.
14. Thomas Kuyk et al., "Health-Related Quality of Life Following Blind Rehabilitation," *Quality of Life Research* 17, no. 4 (2008): 497-507.
15. Wittenborn, John and Rein, David. Cost of Vision Problems: The Economic Burden of Vision Loss and Eye Disorders in the United States. 6-11-2013. Chicago, Prevent Blindness America. 7-28-2013. Ref Type: Report
16. Sherry L. Murphy, Jiaquan Xu, and Kenneth D. Kochanek, "Deaths: Preliminary Data for 2010," *National Vital Statistics Reports* 60, no. 4 (2012).
17. "Baseline Economic Forecast—February 2013 Baseline Projections,", Congressional Budget Office (2013; <[28] Date).

18. "Consumer Price Index,", U.S.Bureau of Labor Statistics (2013; <[28] Date).
19. Marthe R. Gold, *Cost-effectiveness in health and medicine*: Oxford University Press, 1996).
20. "NHE Fact Sheet,", Centers for Medicare and Medicaid Services (2013; <[28] Date).
21. Kevin D. Frick et al., "Direct Costs of Blindness Experienced by Patients Enrolled in Managed Care," *Ophthalmology* 115, no. 1 (2008): 11-17.
22. Joel E. Segel, "Cost-of-Illness Studies – a Primer," *RTI-UNC Center of Excellence in Health Promotion Economics* (2006): 1-39.
23. "Current Population Survey,", U.S.Census Bureau and U.S.Bureau of Labor Statistics (2013; <[28] Date).
24. Antoine Lafuma et al., "Evaluation of Non-Medical Costs Associated With Visual Impairment in Four European Countries," *Pharmacoeconomics* 24, no. 2 (2006): 193-205.
25. "Cornea transplant,", Mayo Clinic (2011; <[28] Date).
26. "Medicare & Medicaid Statistical Supplement,", Centers for Medicare and Medicaid Services (2013; <[28] Date).

Appendix

Table 1: ICD-9 and CPT-4 procedure codes associated with corneal transplant procedures

Procedure	ICD-9 procedure codes	CPT-4 codes
Lamellar keratoplasty	11.61 (Lamellar keratoplasty with autograft) 11.62 (Other lamellar keratoplasty)	**65710** Keratoplasty (corneal transplant); anterior lamellar;
Penetrating keratoplasty	11.63 (Penetrating keratoplasty with autograft) 11.64 (Other penetrating keratoplasty)	**65730** Keratoplasty (corneal transplant); penetrating (except in aphakia or pseudophakia);
		65750 Keratoplasty (corneal transplant); penetrating (in aphakia);
		65755 Keratoplasty (corneal transplant); penetrating (in pseudophakia);
Endothelial keratoplasty	11.69 (Other corneal transplant) 11.60 (Corneal transplant, not otherwise specified)	**65756** Keratoplasty (corneal transplant); endothelial.
		65757 Kor backbench preparation of corneal endothelial allograft prior to transplantation

Table 2: ICD-9 diagnosis codes associated with pre- and post-procedure care

ICD-9	Diagnosis
V7260	Laboratory examination, unspecified
V7261	Antibody response examination
V7262	Laboratory examination ordered as part of a routine general medical examination
V7263	Pre-procedural laboratory examination
V7269	Other laboratory examination
V7281	Pre-operative cardiovascular examination
V7282	Pre-operative respiratory examination
V7283	Other specified pre-operative examination
V7284	Unspecified pre-operative examination
V7285	Other specified examination
0532	Herpes zoster with ophthalmic complications
0544	Herpes simplex with ophthalmic complications
99651	Mechanical complication of other specified prosthetic device, implant, and graft due to corneal graft
V425	Cornea replaced by transplant
3600	Purulent endophthalmitis
3601	Other endophthalmitis
3603	Hypotony of eye
36040	Degenerated globe or eye, unspecified
36041	Blind hypotensive eye
36042	Blind hypertensive eye
36043	Hemophthalmos, except current injury
361	Retinal detachments and defects
3620	Diabetic retinopathy
3621	Other background retinopathy and retinal vascular changes
3622	Other proliferative retinopathy
3623	Retinal vascular occlusion
3624	Separation of retinal layers
3625	Degeneration of macula and posterior pole
3626	Peripheral retinal degenerations
3630	Focal chorioretinitis and focal retinochoroiditis
3631	Disseminated chorioretinitis and disseminated retinochoroiditis
3632	Other and unspecified forms of chorioretinitis and retinochoroiditis
3633	Chorioretinal scars
3634	Choroidal degenerations
3636	Choroidal hemorrhage and rupture
3637	Choroidal detachment
3638	Other disorders of choroid
3639	Unspecified disorder of choroid
364	Disorders of iris and ciliary body
365	Glaucoma
366	Cataract
3670	Hypermetropia
3671	Myopia

3672	Astigmatism
3673	Anisometropia and aniseikonia
3681	Subjective visual disturbances
3682	Diplopia
370	Keratitis
371	Corneal opacity and other disorders of cornea
372	Disorders of conjunctiva
373	Inflammation of eyelids
374	Other disorders of eyelids
375	Disorders of lacrimal system
3770	Papilledema
3771	Optic atrophy
3772	Other disorders of optic disc
3773	Optic neuritis
3774	Other disorders of optic nerve
3785	Paralytic strabismus
3786	Mechanical strabismus
3790	Scleritis and episcleritis
3791	Other disorders of sclera
3792	Disorders of vitreous body
3793	Aphakia and other disorders of lens
3794	Anomalies of pupillary function
3796	Inflammation (infection) of postprocedural bleb
3798	Other specified disorders of eye and adnexa
3799	Unspecified disorder of eye and adnexa

Table 3: Descriptive statistics of cost of keratoplasty procedures by age-group and type of service

Patient's Age		Under 65			65 and older		
Procedure	**Statistic**	**Penetrating**	**Endothellial**	**Lamellar**	**Penetrating**	**Endothellial**	**Lamellar**
Anesthesia	sample size	505	200	45	286	508	15
	average cost	$1,085	$1,024	$1,309	$236	$236	$252
	median cost	$902	$821	$1,045	$225	$212	$263
Physician	sample size	537	219	63	323	537	17
	average cost	$1,634	$1,782	$1,563	$2,088	$2,449	$1,949
	median cost	$1,322	$1,463	$1,207	$1,960	$2,666	$2,399
Facility*	sample size	633	368	105	165	223	5
	average cost	$5,196	$4,517	$3,889	$6,216	$7,302	$5,525
	median cost	$4,305	$3,194	$2,717	$5,935	$6,594	$5,712
Pre-op	sample size	363	194	42	231	369	14
	average cost	$1,284	$1,655	$770	$1,040	$1,119	$509
	median cost	$473	$564	$556	$409	$573	$423
Post-op	sample size	352	155	40	221	310	11
	average cost	$9,509	$11,774	$3,332	$7,004	$5,037	$7,973
	median cost	$1,694	$2,407	$1,402	$2,045	$2,185	$1,808
Medications	Average/ median cost	$200	$200	$200	$200	$200	$200
Total	average cost	$18,907	$20,953	$11,062	$16,783	$16,343	$16,408
	median cost	$8,897	$8,649	$7,127	$10,775	$12,430	$10,806

Source: Data for population under age 65 is obtained from OptumInsight dNHI database and for population age 65 or older from Medicare 5% SAF.
*Includes tissue fee