Cost Benefit Analysis: Cornea Transplantation

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Introduction

This document analyzes the costs and benefits associated with corneal transplantation.

Corneal damage and disease adversely impacts quality of life. According to the CNIB, those waiting for a corneal transplant are generally suffering from vision loss or pain that "interferes with daily activities such as driving, reading or working at a computer."[1]

According to Roussy et al (2009)[2], the leading indications for corneal transplant in Canada were:

- Pseudophakic bullous keratopathy, a complication of cataract surgery, which accounted for 28.5% of cases;
- Deterioration of a previous graft necessitating a regraft (22.3%);
- Keratoconus;
- Fuchs' dystrophy;
- Viral infection; and
- Trauma.

Cornea transplantation surgery is generally performed on an outpatient basis. Two types of transplant procedures can be performed:

- A penetrating keratoplasty (PK), where a damaged or diseased cornea is replaced in entirety with a donor graft; or
- Lamellar (or non-penetrating) keratoplasty, where the outer two-thirds of the cornea is removed and replaced with donor cornea.

The technique of posterior lamellar keratoplasty (PLK) has been introduced relatively recently. Beauchemin et al (2010)[3] showed that while success rates with PK were high and resulted in better visual acuity relative to PLK, transplant rates were limited by a shortage of corneal tissue and therefore, lengthy wait times from diagnosis to surgery. PLK, on the other hand, could be used only to treat epithelial corneal disease, but led to substantially lower rates of graft rejection, less astigmatism, fewer suture-related complications and more rapid visual recovery (although not to the visual acuity level afforded by PK). In addition, tissue that was often not suitable for PK (i.e. tissue with anterior corneal damage) could be used for PLK. According to Beauchemin et al, PLK was less expensive 'over a lifetime horizon' compared to PK and also more effective, providing more quality-adjusted life years (QALYs). The difference in QALYs was attributed to several different factors: lower wait times, shorter recovery times, substantially lower graft rejection rates and fewer suture-related complications.

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[1] http://www.cnib.ca/en/your-eyes/ask-expert/corneal-transplant/

[2] Roussy JF, M Aubin et al, "Cost of Corneal Transplantation for the Quebec Health Care System." Can J Ophth (2009), 44(1):36-41.

[3] Beauchemin C, Brunette I et al, "Economic impact of the advent of posterior lamellar keratoplasty in Montreal, Quebec." Can J Ophth (2010), 45(3): 243-251.

Current Costs of Corneal Transplantation

The estimated current system costs for corneal donation and transplantation average $7400 per cornea (2010 CAD). This cost estimate assumes that: all donor costs were for cornea and that sclera costs were negligible[4]; cornea yield per donor ranges from 1.1 to 1.3; one cornea is transplanted per procedure; and costs increased by 3% per annum to reflect 2010 costs.

The table below, from a Canadian Blood Services costing exercise, provides details behind the calculations for corneal transplantation costs, excluding cost of cornea donation. Hospital costs and anaesthesiologist fees were based on Alberta data (which was the only data available at the time); hospital-based surgeon fees were based on a mix of Alberta, British Columbia and Ontario data; while pharmacy and outpatient medical visit costs were calculated using Quebec data. For the exercise it was assumed that penetrating and lamellar keratoplasties were performed in equal proportions.

Details on Transplantation Costs (2010 $)

Cost Category	Assumptions	$ per Corneal Transplant
Hospital Costs	Based on average inpatient cost in Alberta 2004/05 - adjusted for inflation (3% per year) compounded over 4 years	$ 3,107
Hospital-based Surgeon Fees	- Averaged Physician Fees for lamellar and pentrating corneal transplants (assume equal proportions) - Assumed that neuro consults were required in BC for 20% of cases - Calculated weighted average for BC (10%), AB (10%), ON (40%) volumes	$ 754
Hospital-based Anaesthesiologist Fees	- Averaged Alberta anaesthesia fees	$ 246
Pharmacy Costs (outside hospital)	-Multiplied Quebec pharmacy costs by ratio of Canada ($3016): Quebec ($1942) hospital costs	$ 555
Medical Visits	-Multiplied Quebec medical visits costs by ratio of Canada ($3016): Quebec ($1942) hospital costs	$ 455
TOTAL COST per CORNEAL TRANSPLANT		**$ 5,117**

Roussy et al (2009) calculated that the initial cost of providing a corneal graft (physician billing and hospital costs only) to be $3171. They did not differentiate between penetrating and non-penetrating keratoplasty. It is assumed, based on the study sample and the average three year follow-up period, that this cost estimate reflects 2002 costs. At an annual compounded inflation rate of 3%, this translates to $4,017 in 2010 dollars. The transplantation cost estimate (physician billing and hospital costs only), according to calculations from the Canadian Blood Services costing exercise (above), amounts to $4,107, a difference of 2%.

The estimated cost of a corneal donation ranges from $2100 to $2500[5] per cornea (2010 CAD), depending on average donor yield and varying cost estimates (average = $2300/cornea). The average cost estimate for importing a full thickness, not pre-cut cornea from the US is approximately $2500. This represents a 9% increase over average domestic cornea donation costs. It also represents an increase of 3% in total corneal donation and

[4] In actuality, 1/8 of annual ocular activity is related to sclera although the majority of costs can be attributed to corneal donations.

[5] Estimate based on variable costs related to Screening & Recovery, Testing, Processing, Storage & Distribution, Quality Assurance), and fixed costs related to Capital, Salaries and Wages, Quality Assurance and other Fixed Costs.

transplantation costs, assuming an average cost of $7400 for domestic cornea with an incremental $200 for importation. The cost of importing a pre-cut cornea is approximately $3200 per cornea.

Analysis of Payback

Waitlist management processes for corneal transplantation in Canada vary from province to province and from eye bank to eye bank. Wait time statistics, therefore, are not readily available. It has been stated, however, that cornea wait times can range from six months to three years per eye. If it is assumed that additional wait times do not compromise clinical outcomes of transplantation surgery and that at some point, everyone requiring a corneal transplant will receive one, then it can be assumed that increasing the volume of available corneas for transplant will decrease a patient's wait time and substantially enhance quality of life earlier. (See "Analysis of Societal Benefits" for discussion on the impact of vision loss on quality of life and productivity.

Even so, an exercise comparing the cost of corneal transplantation to the cost of not receiving a transplant reveals that transplantation would have a payback period of approximately four years, after which point considerable cost avoidance would be achieved. The assumptions required for this analysis are described in the following paragraphs; however, it is important to note that these assumptions are conservative in nature and may overestimate the length of the payback period for corneal transplantation.

The CNIB has estimated the annual direct health system costs due to vision loss to be $10,750 per person with vision loss in 2007 ($11,747 in CAD2010) if inflated at an annual compounded rate of 3%.[6] This estimate includes costs of vision care, hospital and medical care, physicians' services and other institutional care. If only pharmaceutical and vision care expenses are included, the average annual expense is $5,412, of which, for the purposes of this analysis, 50% was attributed to public payers.

For the payback analysis below, the cost of corneal transplantation costs was estimated to be $7400 per cornea (including donation costs). It was assumed that transplantation occurred halfway through Year 1, with medical management being required for the initial six month period. Year 2 and 3 post-transplant costs were estimated at 20% of pre-transplant costs as the transplant cost estimates include follow-up care costs for three years. Post-transplants costs Year 4 onwards were estimated to be 50% of pre-transplant costs. Graft failure rates were not factored into the calculations.[7]

The payback analysis takes the perspective of the public payer for the health care services in question. Any benefits in productivity or economic contribution due to improved vision from the transplant are additional to the calculations in the payback analysis.

[6] This estimate was derived using a 'bottom-up' approach by calculating direct health system expenses attributable to vision loss for five major eye diseases: age-related macular degeneration, cataract, diabetic retinopathy, glaucoma, refractive error and other causes of vision loss. It is assumed that this annual estimate represents the experience of those with corneal disease awaiting a corneal transplant.

[7] A longitudinal review of 4000 PK procedures from 1982 to 1996 found survival of first time grafts to be 90% at five years and 82% at 10 years (Thompson RW, MO Price et al, "Long-term Graft Survival after Penetrating Keratoplasty." Ophthalmology (July 2003) 110(7): 1396-1402). More recent advancements in surgical techniques (e.g. lamellar keratoplasty) and medical management may have resulted in even higher graft survival rates.

Payback Analysis of Corneal Transplantation versus No Transplantation

(conservative estimate)

Net Savings from Tx (per Patient)	***Year 1***	***Year 2***	***Year 3***	***Year 4***	***Year 5***
Annual Expenses of Managing Corneal Disease	$2,700	$2,781	$2,864	$2,950	$3,039
Corneal Transplant and Post-Management Expenses	$8,750	$556	$573	$1,475	$1,519
Net Difference per Patient	-$6,050	$2,225	$2,292	$1,475	$1,519
Estimated Accumulated Savings	*-$6,050*	*-$3,825*	*-$1,534*	*-$58*	*$1,461*

Assumptions:

- average annual health system expense (conservative) from CNIB: $11,550 2010 CAD ($10,570 2007 CAD at 3% annual compounded inflation)
- assume waiting for transplanation costs limited to pharmaceutical and vision care costs (46.9%) = $5,412
- assume 50% of costs from public purse; 50% from private payers ($2,700)
- assume average cost of a corneal transplantation, including donation, is $7400.
-assume transplantation occurs mid-cycle, after 6 months of pre-tx management and care
- assume Year 2 and 3 follow-up costs post-transplantation are 20% of pre-tx costs b/c transplant estimates include 3 years of follow up costs
- assume Year 4 onward costs post-transplantation are 50% of pre-transplant costs

Analysis of Societal Benefits

Burden of Illness

In 2008, CNIB commissioned a report documenting the magnitude of the cost of vision loss in Canada. According to this report:

- Vision loss has the highest health care direct costs of any disease category in Canada, including diabetes, cardiovascular disease and cancers. This includes the cost of vision care (eye care professionals and corrective lenses), hospital care, physician services, etc.
- Vision loss is also cause for huge overall financial expenditures, mostly due to loss in productivity to the economy, which accounts for 62% of total indirect costs. Other indirect costs include transfer costs (or deadweight losses) - for example costs associated with raising additional tax revenues to cover programs such as income tax deductions – and the cost of care and rehabilitation provided by friends and family.
- Compared to sighted people, those with vision loss experience two to five times more difficulty with the activities of daily living, three times as much clinical depression, twice as much social dependence, a greater number of medication errors, twice the risks of falls and premature death, four times the risk of serious hip fractures and earlier admissions to nursing homes.

In its paper, the CNIB references a previous survey "revealing that two-thirds of Canadians would cash in all their savings or sell everything they owned to save their eyesight."[8]

Ability to work

The CNIB reports that "half of adults with vision loss live in poverty."[9] The employment rate of working age adults with significant vision loss is only 32%. Once again, because the criteria to be placed on a corneal transplant wait list is directly related to visual impairment and pain, it can be assumed that the great majority of those awaiting corneal transplants who are of working age experience difficulties on the job.

[8] Ibid, p. 95.

[9] Access Economics Pty Ltd, "The Cost of Vision Loss in Canada," for CNIB and the Canadian Ophthalmological Society, 2009.

Ability of Corneal Transplantation to Restore Vision Loss

Those on a corneal transplant wait list generally suffer from either significant vision loss and/or pain. Mendes et al (2003)[10] demonstrated via a multi-centre prospective study in the USA that the median preoperative visual acuity was 20/200[11]. Median best-corrected postoperative visual acuity[12] in the operated eyes was 20/60 after six months. Greatest improvement was seen in those with poorer pre-operative visual acuity. Postoperatively, 80% of patients were "moderately to very satisfied" with their vision. Ninety-seven percent of patients stated they would have the surgery again.

A German cost utility study for PK reported median pre-operative and post-operative visual acuity levels of 20/160 and 20/46 respectively.[13]

As part of their modeling exercise, Beauchemin et al used average pre-operative vision acuity of the better-seeing eye to be 20/200; post-operative average vision acuity was established at 20/60 by 12 months post-surgery.

Cost Effectiveness

In Canada, a health intervention is generally considered to be cost-effective if it costs less than approximately $40,000-$50,000/QALY. According to Hirneiss et al (2006), over ten years after PK surgery, considering graft survival and discounting, a cost utility of $11,557 USD was gained. This is well within the acceptable limits for cost effectiveness in Canada and can be attributed to the substantial gain in quality of life relative to the cost and maintenance of a transplant.

Ament et al[14] synthesized research from numerous research papers to develop a comparative list of the cost utility of select common interventions including PK and synthetic cornea implants (Boston keratoprosthesis), demonstrating the relative cost-effectiveness of corneal transplants (and synthetic implants).

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[10] Mendes F, DA Schaumberg et al, "Assessment of visual function after corneal transplantation: the quality of life and psychometric assessment after corneal transplantation (Q-PACT) study." Amer J Ophth (June 2003), 135(6):785-793.

[11] Visual acuity of 20/200 is generally considered as 'legally blind'.

[12] "Best-corrected visual acuity" refers to "the best possible vision a person could achieve with corrective lenses measured in terms of Snellen lines on an eye chart." Source: Access Economics Pty Ltd, "The Cost of Vision Loss in Canada," for CNIB and the Canadian Ophthalmological Society, 2009.

[13] Hirneiss C, AS Neubauer et al, "Cost Utility for Penetrating Keratoplasty in Patients with Poor Binocular Vision." Ophthalmology (2006), 113: 2176-2180.

[14] Ament JD, TP Stryjewski et al, "Cost-Effectiveness of the Boston Keratoprosthesis." American Journal of Opththalmology (Feb 2010) 149(2): 221-228.

Cost Utility of Various Medical Interventions in the United States, Adjusted to 2009 US Dollars

Intervention	Cost in $/QALY
Initial cataract surgery	2,023
Second eye cataract surgery	2,727
Penetrating keratoplasty	12,194
Boston Keratoprosthesis (submitted paper)	16,140
Photodynamic therapy for subfoveal choroidal neovascularisation with ARMD	
20/40 initial vision	104,158
20/200 initial vision	208,966
Coronary bypass surgery for occluded LAD artery	44,113
Chemoprophylaxis after occupational exposure to HIV	49,036
Primary pediatric heart transplant	52,417
Magnetic resonance imaging for equivocal neurologic symptoms	134,742
One day of chemoprophylaxis prior to receiving dental work for patients with prosthetic joints	696,892

ARMD = age-related macular degeneration; HIV = human immunodeficiency virus; LAD = left anterior descending