Use of Global Visual Acuity Data in a Time Trade-off Approach to Calculate the Cost Utility of Cataract Surgery

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Objective: To determine the cost utility of cataract surgery worldwide using visual acuity (VA) outcomes and utility values determined by the time trade-off (TTO) method.

Data Sources: Some cost data were taken from a previous search conducted for 1995 to 2006 and we searched MEDLINE and Scopus and Google for more recent data (2006 and 2007).

Study Selection: Articles were identified from the literature using "cataract surgery" in combination with the terms *outcome* or *visual acuity*. Additional searches were conducted using individual countries as a term in combination with VA, outcome, or cost. Regression curves were constructed from utility values derived from a TTO study and VA data. Gains in quality-adjusted life-years (QALYs) were calculated based on life expectancy tables from the World Health Organization and discounts of 3% for both cost and benefit. Sensitivity analyses explored the effect of changes in discounting, life expectancy, preoperative VA, and cost.

Data Extraction: If the data were usable, they were kept; otherwise they were discarded.

Data Synthesis: Preoperative VA (logMAR) correlated with increasing gross national income per capita (Pearson correlation coefficient, –0.784; $P < .001$) and showed that in developing countries preoperative vision is much poorer compared with developed countries. Cost utility data ranged from \$3.5 to \$834/QALY in developing countries to \$159 to \$1356/QALY in developed countries. Sensitivity analysis showed that changing life expectancy, VA, and discount rate resulted in moderate changes.

Conclusions: The TTO approach demonstrates that cataract surgery is extremely cost-effective.

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Although visual impairment due to cataract is not a major issue in developed countries, in developing countries increasing cataract surgery rates to treat backlogs and meet the demands of an aging population are still a challenging problem, despite advances in surgical techniques and the manufacture of low-cost intraocular lenses (IOLs).[1]

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Cost-effectiveness studies can quantify the effect of a treatment in terms of the quality of life from the recipient's point of view, as well as incorporating its cost to individuals or society, and represent one approach to decision making in health care.[2,3] If comparable methods are used, treatments or interventions can thus be compared and ranked as being more or less cost-effective. When the study uses the concepts of utility and quality-adjusted life-years (QALYs),[4] it is termed a *cost utility study*. In brief, QALYs are years of healthy life lived and are calculated from the difference in utility values before and after

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an intervention or treatment using a scale in which 1 = perfect health and death = 0, multiplied by the number of years over which the treatment or intervention is effective. So, for example, if the life expectancy of an individual is 10 years at the time of cataract surgery, and the utility values are 0.85 and 0.95 for preoperative and postoperative conditions, respectively, then the number of QALYs gained would be $10 \times (0.95 - 0.85) = 1$.

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In a previous study,[5] we explored the few cost utility studies that had been conducted in single countries using the time trade-off (TTO) method and self-assessment scales. Using the utility values derived from Busbee et al[6] and Kobelt et al,[7] as well as cost data from several other countries, we calculated a range of possible cost utility values for cataract surgery. When generic quality-of-life instruments, such as the 15D[8] and EQ-5D,[7] are used to estimate utility values, the changes are relatively small, from 0.01 to 0.03. However, when the TTO approach is used, the utility change is an order of magnitude larger: 0.148 for surgery of the first eye.[6]

In addition to the different methods one can use to obtain utility values, one must also consider the status of the companion eye. Brown[9] maintains that the TTO approach to measuring utility better correlates with vision and quality-of-life issues in comparison with self-assessment scales. Furthermore, Brown et al[10] concluded that a positive utility value change of about 0.08 is obtained when a visually impaired eye is treated for ocular disease, with resultant good visual acuity (VA) for the case in which the companion eye already has good VA. While Busbee et al[6] included the complications of cataract surgery in their calculation of the utility change associated with cataract surgery of the first eye, because of lack of VA data for the companion eye, they assumed its VA would be the same as the preoperative value for the eye that would receive surgery. However, they have pointed out—and we agree—that the resultant utility gain can be overestimated if the companion eye has good or better vision than the eye to be operated on.

Using TTO-derived utility values for a scale of VA from 20/20 to no light perception in the better-seeing eye,[11] we investigated the cost utility of cataract surgery using outcome data from dozens of different studies around the world. Our goals of the study were 3-fold: to (1) calculate the cost utility of cataract surgery in both developing and developed countries, (2) estimate the correction to cost utility values obtained in cases in which the VA of the companion eye is substantially different from the operated-on eye, and (3) compare the calculated cost utility values with a variety of benchmarks to assess the cost utility of cataract surgery.

METHODS

COST

Some cost data for cataract surgery were taken from a previous search conducted for 1995 to 2006.[5] In addition, we searched MEDLINE and Scopus for more recent data (2006 and 2007) using the terms *cost + cataract surgery*. Publications written in other languages besides English were not excluded. Additional cost data were uncovered by searching Google using the terms *cataract surgery + cost + country* (ie, India or Nepal) (eTable 1, http://www.archophthalmol.com). However, these data were not used unless they were government data or the publication was authored by a person who had previously published in peer-reviewed ophthalmology or health economics journals.

Costs were first converted to dollars by using Federal Reserve historical foreign exchange rates (www.federalreserve.gov/RELEASES/H10/hist/; accessed November 23, 2007) and then adjusted to 2004 prices by using Consumer Price Index data conversion factors (http://oregonstate.edu/cla/polisci/faculty-research/sahr/infcf17742008.pdf; accessed March 18, 2009).

Although some disagreement exists regarding how much discount must be applied to discount future benefits, we followed the US Panel on Cost-Effectiveness in Health and Medicine recommendation of a 3% discount rate for both costs and benefits.[12] Costs were thus discounted at 3% based on the life expectancies of individuals in a given country.

GROSS NATIONAL INCOME AND LIFE EXPECTANCY DATA

Gross national income (GNI) per capita for 2004 for each country (Atlas method) was obtained from the World Bank (http://web.worldbank.org; accessed September 12, 2007).

Life expectancies were calculated based on the mean age of each study cohort or cohorts and the year in which the study was conducted, matching the study year as closely as possible to the available years for actuarial tables. Actuarial tables provided by the World Health Organization for 2000 to 2005 (www.who.int/whosis/database/life/life_tables/life_tables.cfm; accessed November 13, 2007) were used to calculate the life expectancy of each study cohort or cohorts using combined sex data. Life expectancies were available in increments of 5 years for the age of individuals, and a regression analysis was performed for life expectancy vs age for each country based on these data to improve accuracy by interpolation. Using mean age of the study cohort as the age parameter and the regression equation for each country, we then calculated the life expectancy.

VA DATA

Pertinent articles on the subject of VA outcome in cataract surgery were identified by searching MEDLINE and Scopus from 1996 to 2007, using the phrase "cataract surgery" in combination with the terms *outcome* or *visual acuity*. Additional searches were conducted for specific countries, using individual countries as a term in combination with "cataract surgery" and "outcome." Articles were selected on the basis of providing clear VA data (uncorrected or best-corrected) for both preoperative and postoperative groups of patients. In 2 instances, we deviated from this practice because we felt the data were important. For 3 articles dealing with China, we adopted a mean preoperative VA of 3/60, and for Ethiopia, we used the survey data of Melese et al[13] to calculate a mean preoperative value. For studies that were randomized controlled trials, we combined the data for both groups where possible.

CONVERSION OF VA DATA

Mean visual acuities reported in logMAR units were directly used. If ranges were given, arithmetic means were calculated based on the prevalence for each range. If geometric mean Snellen VA values were reported, these were converted to decimal figures and then logMAR units by inverting the values and calculating the logarithms. If ranges were given, the VA in logMAR units was calculated for each range and the arithmetic mean calculated based on the prevalence given for each range. For the lowest range with an unspecified lowest value (eg, ≤3/60, the definition of blindness), we took the value 0.01 and the value of the specified VA and averaged these values after first converting them to logMAR units. At the high end of the scale, if no upper limit was defined for a preoperative range (eg, >3/60), we added 0.1 Snellen decimal unit to create the upper range and then converted the values to logMAR units before averaging. Thus, in this example (>3/60), the decimal Snellen values would be 0.05 and 0.15. In the case of postoperative values (eg, ≥6/9), we assigned a Snellen decimal value of 1.0 for the upper range.

COST CALCULATIONS

Where several studies of costs were available, these were averaged prior to discounting unless otherwise stated.

For Brazil, the cost of extracapsular cataract extraction (ECCE) was determined by dividing the cost for phacoemulsification by 1.26; this factor was calculated by separately averaging the costs for ECCE and phacoemulsification taken from 5 studies/reports.[14-18]

For China, rural costs were averaged,[19,20] and this figure was averaged with the provincial cost[20] to determine the rural cost of cataract surgery. For cataract surgery studies conducted in Chinese cities, such as Hong Kong,[21] the cost of cataract surgery used the city cost figure from Tan.[20]

For India, the cost of intracapsular cataract extraction or ECCE in camps (without IOLs) used the costs from Singh et al[22] (camp provider costs) and was only applied to the studies of Verma et al[23] and Kapoor et al.[24] For the Kapoor et al study[24] (ECCE + IOLs), an additional $10 was added to the basic cost. For the study of Prajna et al,[25] hospital costs for intracapsular cataract extraction/ECCE were taken from Singh et al[22] and averaged. However, for the eye camp study of Balent et al[26] and all other Indian studies, the costs used were averages for ECCE, manual small-incision cataract surgery, and phacoemulsification taken from Muralikrishnan et al[15] and Gogate et al.[27,28]

For Singapore, the costs of cataract surgery and the VA outcomes for 1 study (Saw et al[29]) were adjusted to reflect the percentages of phacoemulsification and ECCE used.

CALCULATION OF COST UTILITY

Using the utility data for VA reported by Brown et al,[11] a regression analysis was performed and a third-order polynomial equation was fitted to the VA data on a log-linear scale (**Figure 1**). Details of this equation and the one used to calculate cost utility are found in eTable 2.

ESTIMATION OF UTILITY GAIN USING VA DATA FROM OPERATED-ON AND COMPANION EYES

While utility values better correlate with VA in the better-seeing eye,[30] the majority of data available for VA outcomes of cataract surgery are for the operated-on eye. If the difference in VA between the operated-on eye and the companion eye is substantial, there is likely to be an error in using the utility value based on the preoperative VA of the operated-on eye. This error leads to a larger change in utility values from cataract surgery than would be expected if the VA of the companion eye had been used as the basis for the calculation. An estimate of this error was obtained by comparing 2 scenarios: (1) change in utility using the worse-eye preoperative and postoperative VA data and (2) change in utility using the preoperative VA of the companion eye and the postoperative VA of the operated-on eye in 5 cataract surgery studies in which data were available for each eye.[7,31-34]

SENSITIVITY ANALYSIS

To explore the robustness of our methods, using the base case of 3% discounting (costs and QALYs gained), we examined the effect of changing the following variables: life expectancy (±2.5 years); change in decimal VA (±10%); discount rate (0%-5%); and additional costs (cost +25%, 3-fold increase in costs).

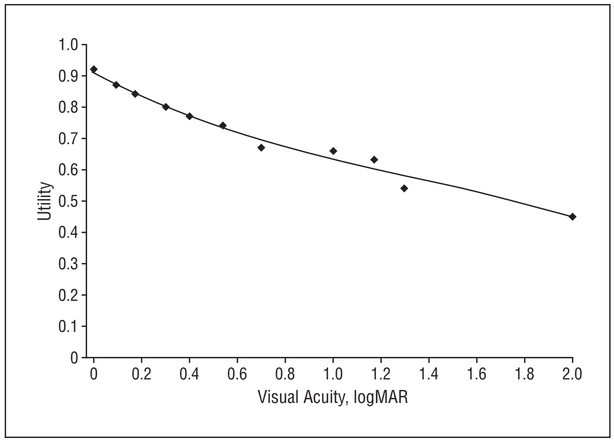

Figure 1. Regression line (third-order polynomial) for fitting utility results to visual acuity (logMAR) on a log-linear plot, using data from Brown et al.[11]

COMPUTATIONS AND STATISTICS

All computations were carried out using Excel (Microsoft, Redmond, Washington). Correlations were calculated using SPSS v.16 (SPSS Inc, Chicago, Illinois). A P value of $<.05$ was considered statistically significant.

RESULTS

COSTS AND VA

Undiscounted costs are shown in **Table 1** by country. Preoperative and postoperative VA data, together with descriptions of the type of surgery performed, number of eyes in each study, and other remarks, are shown in **Table 2**, also by country. The number of eyes in each study was taken from postoperative data because this number was usually smaller than the number for preoperative data. When preoperative and postoperative VA data were plotted against GNI per capita for each study and its respective country, the preoperative VA showed a definite trend toward better vision with increasing GNI per capita (Pearson correlation coefficient, −0.784; $P<.001$), but the postoperative VA showed a correlation line with a smaller slope (Pearson correlation coefficient, −0.572; $P=.005$) (**Figure 2**). Among developing countries, the largest differences between preoperative and postoperative VAs were found for Kenya and Uganda, while the smallest differences were found for China and Ethiopia (**Figure 3**). Among developed nations, the largest differences were found for Malaysia, Spain, and New Zealand, while the smallest differences were found for Australia, Finland, and the United Kingdom (**Figure 4**).

COST UTILITY

For developed countries, undiscounted mean utility gains (unweighted with respect to number of eyes in each study) ranged from 0.108 in the United Kingdom to 0.217 in New Zealand. In developing countries, the range was from 0.059 in Ethiopia to 0.274 in Kenya, with a mean of 0.196 for India. The mean utility gain for developed countries (0.159) was less than that for developing countries (0.190).

Table 1. Costs of Cataract Surgery for the First Eye Calculated for Different Countries

Country	Year Costs Calculated	Cost Undiscounted, $[a]	Source
Australia	1993	PH: 1094	Asimakis et al,[14] 1996
Australia	1995	OUT: 1812	Fan et al,[35] 1997
Brazil	2000	PH: 264	Saad Filho et al,[36] 2005
Canada	2003/2004	411	Chen and Arshinoff,[37] 2005
China	2001	Rural: 533-666[b]	He et al,[19] 2007
China	2006	Rural: 187-281; PR: 356-469; city: 590-937	Tan,[20] 2006
China	2006	292-936	Lin,[38] 2007
Denmark	1996	1203	Anderson et al,[39] 1997
Ethiopia	2004	GOV: 23.5; city: 353; rural: 60	Melese et al,[40] 2004
Finland	2002/2003	1466	Räsänen et al,[8] 2006
Germany	1998	1110	Orme et al,[41] 2002
Germany	2003	OUT: 1040	Landwehr et al,[42] 2003
Germany	2004	4183	Pagel et al,[43] 2007
India	1996/1997	ICCE/ECCE (2:1), no IOLs; camps: 48.8; hospitals: 113.1	Singh et al,[22] 2000
India	2000	PH: 27.7; ECCE: 17.7; MSICS: 18.5	Muralikrishnan et al,[15] 2004
India	2004	ECCE: 15.7; MSICS: 15.5	Gogate et al,[27] 2003
India	2004	PH: 47.5; MSICS: 20.8	Gogate et al,[28] 2007
Israel	1991	720	Shmueli et al,[44] 2002
Kenya	2006	94[c]	Lewallen et al,[45] 2006
Malaysia	2000	PH: 1252; ECCE: 1007	Loo et al,[16] 2004
Malaysia	2001	PH: 565; ECCE: 475	Rizal et al,[17] 2003
Nepal	1992	ECCE: 28.9	Marseille,[46] 1996; Marseille and Gilbert,[47] 1996
Nepal	1997	ECCE: 23.2	Ruit et al,[48] 1999
New Zealand	2005	1534	King,[49] 2005
Nigeria	1998	IN[d]: 130	Osahon,[50] 2002
Singapore	2006	PH: 1645; ECCE: 1501	Ganesan,[18] 2006
Spain	1999	OUT: 1024	Castells et al,[33] 2001
Sweden	1998	865	Lundström et al,[51] 2000
Uganda	2006	94[c]	Lewallen et al[45]
United Kingdom	2000	PH: 599; ECCE: 611	Minassian et al,[52] 2001
United Kingdom	1999	649	Afsar et al,[53] 2001
United States	1997 (surgery); 2001 (other costs)	2446	Naeim et al,[54] 2006
United States	2004	3600	Busbee et al,[6] 2002
United States	2006	OUT: 1268	Rein et al,[55] 2006
Zimbabwe	2006	94[c]	Lewallen et al,[45] 2006

Abbreviations: ECCE, extracapsular cataract extraction; GOV, national hospital; ICCE, intracapsular cataract extraction; IN, hospital inpatient; IOL, intraocular lens; MSICS, manual small-incision cataract surgery; OUT, outpatient; PH, phacoemulsification; PR, provincial.
[a]Costs were standardized to 2004 dollars.
[b]Western Guangdong province.
[c]Outreach program that includes costs of transporting patient to surgery center.
[d]Surgery type not identified; IOLs not used.

Cost utility values ranged from $3.5 to $834/QALY in developing countries to $159 to $1356/QALY in developed countries (**Table 3**). Among developing countries, 1 study in China showed the smallest QALY gain (0.381) while the largest was for 1 study in Nepal (3.042 QALYs); QALY gains in India ranged from 0.645 to 2.911. Among the developed countries, the largest QALY gain was found in Germany (2.369) and the smallest, in 1 UK study (0.618).

In the developing world, China and Brazil had the highest cost utility values, while Nepal and India had the lowest values. In developed countries, Australia, Finland, and the United States had the highest cost utility values while cost utility values were the lowest in Canada.

SENSITIVITY ANALYSIS

The results of calculating utility gains from operated-on vs companion eyes showed that the greater the difference in VA between the operated-on and companion eye, the more the apparent utility gain overestimated the true utility gain (**Figure 5**).

The sensitivity analysis showed that changing life expectancy, the postoperative VA resulting from cataract surgery, and the discount rate all resulted in moderate changes (**Table 4**). Although most economists accept the need for discounting future benefits, controversy still exists regarding the rate and whether that rate should be different for costs and health benefits.[84-86] The effect of discounting compared with no discounting reduced cost utility figures by 31% and 20% for discounts of 5% and 3%, respectively. Increasing life expectancy by 2.5 years reduced cost utility by 18%.

COMMENT

Our first goal in this study was to estimate the cost utility for patients undergoing cataract surgery by using a combination of VA outcomes from many different countries and

Table 2. Preoperative and Postoperative VA and Mean Changes[a]

Country	Mean Preoperative VA	Mean Postoperative VA	Mean Change	Remarks	Source
Australia	0.398	0.097	0.301	N=111 (US); postoperative period, 3 mo; surgery type not reported but probably PH	Pager et al,[56] 2004
Australia	0.54	0.07	0.47	N=121 (US); postoperative period, 4 wk; surgery type not mentioned but probably PH	Kirkwood et al,[57] 2006
Brazil	1.253	0.327	0.926	N=1005 (US); postoperative period, unknown; ECCE; CALC (near normal = 0.8 Snellen value)	Nascimento et al,[58] 2004
Canada	0.796	0.180	0.616	N=138 (US); postoperative period, 4 mo; 63% PH; 37% ECCE	Norregaard et al,[59] 1998
Canada	0.824	0.180	0.644	N=111 (US); postoperative period, 4 mo; 64% PH; 36% ECCE	Norregaard et al,[60] 2003
Canada	0.709	0.314	0.395	N=851 (US); postoperative period, 3 mo; CALC	Noertjojo et al,[61] 2004
China (Guangdong)	1.301	0.990	0.311	N=152 (US); assumption: mean preoperative VA, 3/60; CALC; postoperative period, several years; predominantly ICCE	He et al,[62] 1999
China (Tibet)	1.301	0.734	0.567	N=216 (US); assumption: mean preoperative VA 3/60; CALC; postoperative period, several years; VA predominantly uncorrected	Bassett et al,[63] 2005
China (Hong Kong)	1.301	0.583	0.718	N=469 (US); assumption: mean preoperative VA 3/60; CALC; postoperative period, several years; VA pinhole corrected	Lau et al,[21] 2002
Denmark	0.770	0.187	0.583	N=270 (US); postoperative period, 4 mo; 66.7% ECCE; 33.3% PH	Norregaard et al,[59] 1998
Denmark	0.770	0.187	0.583	N=256 (US); postoperative period, 4 mo; 68% ECCE; 32% PH	Norregaard et al,[60] 2003
Ethiopia	0.737	0.495	0.242	N=419 (US); postoperative period, 2 wk; preoperative data calculated from survey data (uncorrected); CALC; ICCE used in 95% of cases	Zerihun,[64] 2001 (postoperative data); Melese et al,[13] 2003 (preoperative data)
Finland	0.557	0.212	0.345	N=148 (BS); postoperative period, 1 mo; PH; CALC; BS	Sarikkola et al,[31] 2004
Germany	0.759	0.058	0.701	N=55 (US); postoperative period, 6 wk; PH	Kohnen et al,[65] 1996
India	1.610	0.697	0.913	N=145 (US); postoperative period, 6 wk; ICCE; CALC; pinhole/BCVA; eye camps	Verma et al,[23] 1996
India	ICCE: 1.862; ECCE: 1.848	ICCE: 0.615; ECCE: 0.509	ICCE: 1.247; ECCE: 1.339	N=3348 (US); postoperative period, 12 mo; ICCE and ECCE; CALC	Prajna et al,[25] 1998
India	1.105	ICCE: 0.394; ECCE: 0.357; ECCE with IOL: 0.348	ICCE: 0.711; ECCE: 0.748; ECCE with IOL: 0.757	N=3908 (US); postoperative period, 6 wk; 51.3% ICCE and 41.2% ECCE (no IOLs); CALC; preoperative VA uncorrected, better-eye data; eye camps	Kapoor et al,[24] 1999
India	1.734	ECCE: 0.812; MSICS: 0.647; PH: 0.580	ECCE: 0.922; MSICS: 1.087; PH: 1.154	N=1034 (US); postoperative period, 8 wk; uncorrected VA; CALC; eye camps	Balent et al,[26] 2001
India	1.393	0.612	0.781	N=2394 (US); postoperative period, predominantly 5 wk; preoperative VA uncorrected; 89.7% ECCE with IOL; CALC	Dandona et al,[66] 2003
India	ECCE: 1.413; MSICS: 1.401	ECCE: 0.259; MSICS: 0.259	ECCE: 1.154; MSICS: 1.142	N=706 (US); postoperative period, 6 wk; ECCE and MSICS; CALC; preoperative VA uncorrected	Gogate et al,[67] 2003
India	0.436	0.236	0.200	N=288 (US); postoperative period, 3 mo; PH; CALC	Mamidipudi et al,[68] 2003
India	1.571	0.282	1.289	N=520 (US); postoperative period, 40 d; MSICS; CALC; preoperative VA uncorrected; postoperative upper limit set to 1.0 Snellen decimal	Venkatesh et al,[69] 2005
Israel	1.608	0.879	0.729	N=150 (US); postoperative period, unknown; presumed to be BCVA but not known; CALC	Leshno and Reuveni,[70] 1999
Kenya	1.683	0.345	1.338	N=1172 (US); postoperative period, 2 mo; ECCE; CALC	Yorston et al,[71] 2002

(continued)

utility values obtained using a TTO approach. As expected, undiscounted utility gains were consistently larger in the majority of cases compared with the utility difference of 0.08 reported by Brown et al,[10] which estimates the utility of second-eye surgery. Busbee et al[6] modeled utility gains for first-eye cataract surgery from the US arm of the US National Cataract Patient Outcomes Research Team study using both VA data and surgical complications encountered 4 months postsurgery and assumed that the VA of the companion eye was the same as the operated-on eye. Their utility gain of 0.148 is similar to the mean utility gain we calculated (0.141) by averaging the data for the 4 US studies reported in Table 3.

In a previous study,[5] we showed that cost utility studies of cataract surgery varied more than an order of magnitude when generic quality-of-life instruments, such as the 15D[7] and EQ-5D,[8] were compared with the TTO approach. The reason is that much smaller changes in utility values are reported by patients in comparison with the TTO approach. This raises the

Table 2. Preoperative and Postoperative VA and Mean Changes[a] (continued)

Country	Mean Preoperative VA	Mean Postoperative VA	Mean Change	Remarks	Source
Malaysia	PH: 1.089; ECCE: 1.607	PH: 0.177; ECCE: 0.268	PH: 0.912; ECCE: 1.339	N=247 (US); postoperative period, 3 mo; CALC	Loo et al,[16] 2004
Nepal	1.329	0.266	1.063	N=251 (US); postoperative period, 2 mo; CALC; ECCE	Ruit et al,[48] 1999
Nepal	1.476	0.260	1.216	N=123 (US); postoperative period, 1 y; ECCE; CALC	Hennig et al,[72] 2003
Nepal	MSICS: 1.308; PH: 1.248	MSICS: 0.130; PH: 0.061	MSICS: 1.178; PH: 1.187	N=108 (US); postoperative period, 6 mo; MSICS and PH; CALC; preoperative VA uncorrected	Ruit et al,[73] 2007
New Zealand	0.88	0.100	0.780	N=488 (US); postoperative period, 4 wk; 97.3% PH	Riley et al,[74] 2002
Nigeria	1.665	0.634	1.031	N=169 (US); postoperative period, 2-4 wk; ECCE; CALC	Alhassan et al,[75] 2000
Singapore	0.600	0.200	0.400	N=460 (US); postoperative period, 3 mo; 71.3% PH; 28.7% ECCE	Saw et al,[29] 2002
Singapore	0.500	0.100	0.400	N=45 (US); postoperative period, ≥6 mo; PH	Wang et al,[76] 2005
Spain	1.155	0.310	0.845	N=161 (US); postoperative period, 4 mo; 97.5% ECCE	Norregaard et al,[59] 1998
Spain	OUT: 1.158	OUT: 0.448	OUT: 0.710	N=464 (US); postoperative period, 4 mo; 82%-84% ECCE; outpatient data, presumed to be BCVA but not reported; CALC	Castells et al,[33] 2001
Spain	1.155	0.310	0.845	N=136 (US); postoperative period, 4 mo; 99% ECCE	Norregaard et al,[60] 2003
Sweden	0.7	0	0.7	N=484 (US); postoperative period not reported; ≥98% PH; data from Swedish Cataract Registry	Kobelt et al,[7] 2002
Sweden	0.854	0.359	0.495	N=438 (BS); PH	Johannson and Lundh,[32] 2003
Sweden	0.222	0	0.222	N=96 (BS); presumably PH; postoperative period, 4 mo	Lundström et al,[34] 2006
Uganda	1.612	0.392	1.220	N=98 (US); 57% ICCE + AC with IOL; 53% ECCE + PC with IOL; postoperative period, ≥1 y; CALC	Waddell et al,[77] 2004
United Kingdom	0.765	0.309	0.456	N=11 143 (US); postoperative period, 3 mo; 77% PH; 23% ECCE; CALC; large study	Desai et al,[78] 1999
United Kingdom	0.482	0.257	0.225	N=362 (US); postoperative period, 2 wk; PH; CALC	Tinley et al,[79] 2003
United Kingdom	0.688	0.204	0.484	N=1000 (US); postoperative period, 1 wk to 9 mo (most common: 2 wk); PH; CALC; VA uncorrected	Zaidi et al,[80] 2007
United States	0.620	0.131	0.489	N=722 (US); postoperative period, 4 mo; 67.3% PH; 32.7% ECCE	Norregaard et al,[59] 1998
United States	0.477	0.097	0.380	N=3342 (US); postoperative period, median 5 wk; 92% PH; 8% ECCE; large study	Lum et al,[81] 2000
United States	0.638	0.131	0.507	N=570 (US); postoperative period, 4 mo; 65% PH; 35% ECCE	Norregaard et al,[60] 2003
United States	0.841	0.303	0.538	N=793 (40% US); postoperative period, 2-4 mo; predominantly PH; VA correction status unknown; CALC	Tobacman et al,[82] 2003
Zimbabwe	1.380	0.550	0.83	N=22 (US), N=15 (BS); postoperative period, 3 mo; ICCE; CALC	Killestein et al,[83] 1997

Abbreviations: AC, anterior chamber; BCVA, best-corrected visual acuity; BS, simultaneous bilateral surgery; CALC, mean preoperative and postoperative VA had to be calculated; ECCE, extracapsular cataract extraction; ICCE, intracapsular cataract extraction; IN, hospital inpatient; IOL, intraocular lens; MSICS, manual small-incision cataract surgery; OUT, outpatient; PH, phacoemulsification; PC, posterior chamber; US, unilateral cataract surgery; VA, visual acuity.

[a] Visual acuity is expressed as BC unless otherwise stated. All VA and mean change values are expressed in logMAR units.

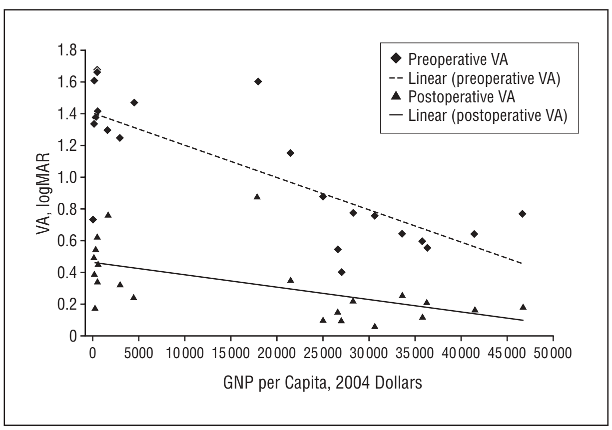

Figure 2. Preoperative and postoperative visual acuity (VA) vs gross national product (GNP) per capita for each study. Solid and dashed lines were fitted to postoperative and preoperative VA, respectively, using linear regression.

question: Which is the more valid method? Although there are no definitive data that will answer this question, a study conducted by Badia et al[87] showed that while the visual analog scales used in the EQ-5D were easier and slightly more reliable than the TTO approach, the TTO approach was more likely to better discriminate between health states and may have greater construct validity. In addition, other instruments that have been used to measure visual disability, including cataract, have been recently criticized on the basis of Rasch analysis, because suboptimal scaling can produce misleading results.[88]

When we compared cost utility for the 4 developing countries from our previous study[7] (Brazil, India, Malaysia, and Nepal) with the corresponding countries in this study, in 3 of the countries (Brazil, Malay-

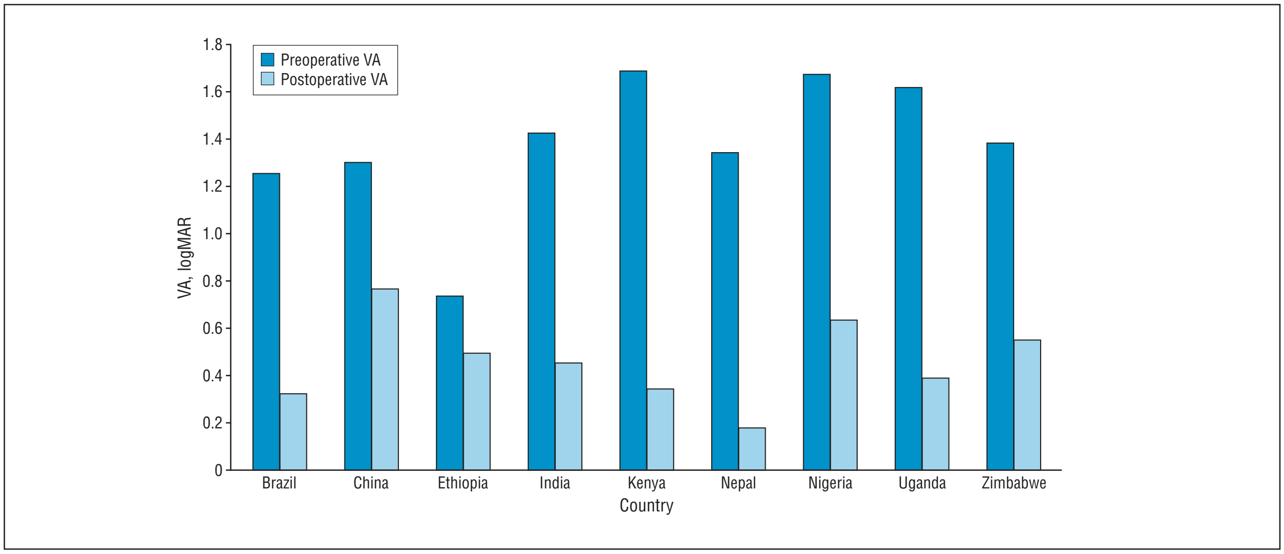

Figure 3. Preoperative and postoperative visual acuity (VA) by country for developing countries.

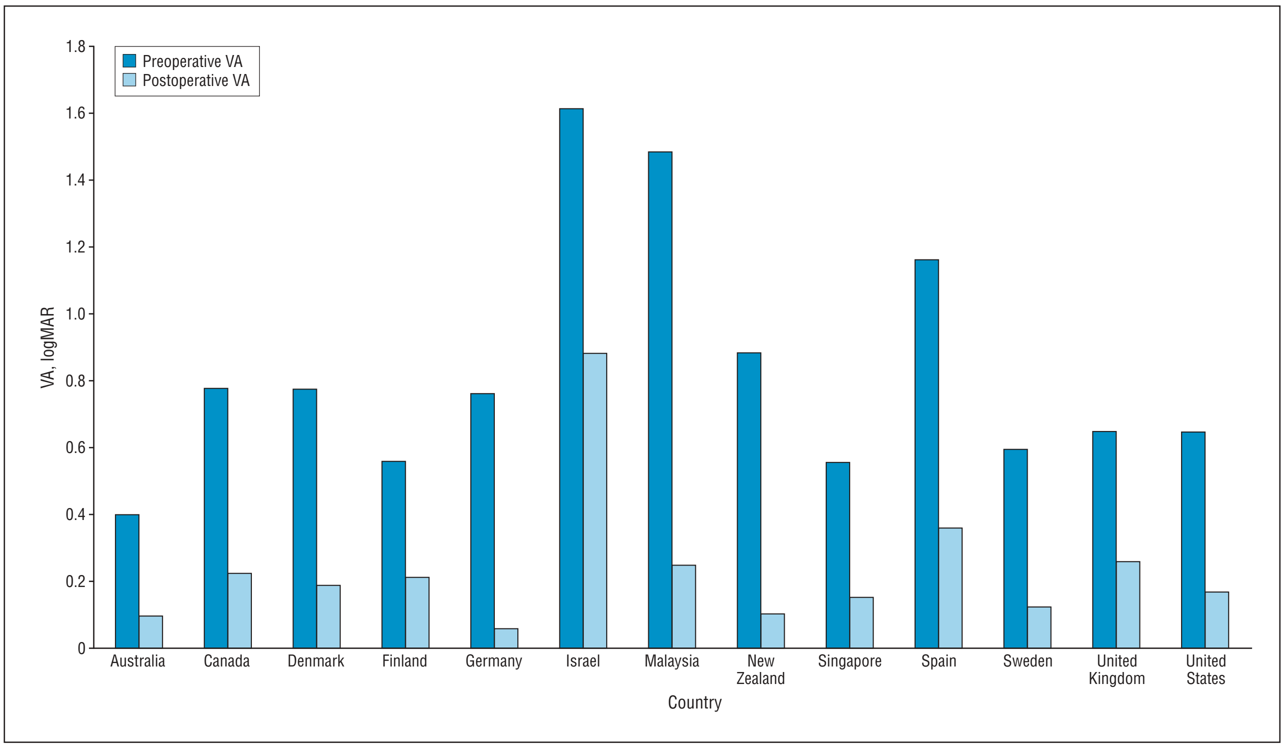

Figure 4. Preoperative and postoperative visual acuity (VA) by country for developed countries.

sia, and Nepal), the cost utilities of cataract surgery were substantially less in this study. In the case of India, the average cost utility was slightly higher in this study than the lowest range for India in the previous study.[5] These differences suggest a lower cost utility using the combination of VA outcomes and the TTO approach in comparison with the generic instrument approach. However, using the TTO approach adopted in this study requires adjustment for the fact that utility correlates better with the better-seeing eye, and our crude estimates (Figure 5) suggest this factor is relatively small when the preoperative VA difference between the worse-seeing and better-seeing eye is small (for example, between 6/60 and 20/60) but is comparatively large for larger differences (for example, between 10/60 and 40/60). We do not know if the difference between apparent and true utility gain for first-eye surgery as we have calculated it continues to increase beyond a certain point. However, the limited data suggest that, on average, true cost utility is approximately double that calculated using preoperative and postoperative VA data from the operated-on eye.

Our findings also confirm that preoperative VA is much better in developed countries compared with developing countries, using GNI per capita as the separating factor.

Table 3. Cost Utility Expressed as Cost per QALY[a]

Country	Mean Age, y	LE, y	Preoperative VA Utility	Postoperative VA Utility	QALY Gain, y	Cost Utility, $/QALY	Source
Developing Countries							
Brazil	67	16.8	0.588	0.793	2.099	60.9	Nascimento et al,[58] 2004
China (Guangdong)	74	9.1	0.580	0.634	0.381	834.0	He et al,[62] 1999
China (Tibet)	65	15.5	0.580	0.721	0.927	643.2	Bassett et al,[63] 2005
China (Hong Kong)	75	8.4	0.580	0.686	1.039	253.6	Lau et al,[21] 2002
Ethiopia	40	28.9	0.685	0.744	0.724	13.8	Zerihun,[64] 2001 (postoperative data); Melese et al,[13] 2003 (preoperative data)
India (ICCE, camps)	64.9	14.5	0.526	0.694	1.588	24.4	Verma et al,[23] 1996
India (ICCE)	56	20.6	0.478	0.714	2.642	23.3	Prajna et al,[25] 1998
India (ECCE)	56	20.6	0.481	0.741	2.911	21.2	Prajna et al,[25] 1998
India (ICCE, camps)	55-60	19.5	0.614	0.773	1.742	19.2	Kapoor et al,[24] 1999
India (ECCE, camps	55-60	19.5	0.614	0.784	1.864	17.9	Kapoor et al,[24] 1999
India (ECCE with IOL, camps)	55-60	19.5	0.614	0.787	1.894	20.6	Kapoor et al,[24] 1999
India (ECCE)	55-60	19.5	0.503	0.669	1.818	5.2	Balent et al,[26] 2001
India (MSICS)	55-60	19.5	0.503	0.706	2.218	4.6	Balent et al,[26] 2001
India (PH)	55-60	19.5	0.503	0.722	2.397	8.8	Balent et al,[26] 2001
India	61	17.1	0.564	0.714	1.545	6.5	Dandona et al,[66] 2003
India (ECCE)	64	14.9	0.561	0.815	2.440	4.4	Gogate et al,[67] 2003
India (MSICS)	64	15.1	0.563	0.815	2.437	4.8	Gogate et al,[67] 2003
India	61	17.2	0.761	0.823	0.645	35.1	Mamidipudi et al,[68] 2003
India	59	18.0	0.533	0.808	2.898	3.7	Venkatesh et al,[69] 2005
Kenya	64	13.7	0.513	0.788	2.506	25.0	Yorston et al,[71] 2002
Nepal	63	14.7	0.575	0.813	2.261	7.5	Ruit et al,[48] 1999
Nepal	53	22	0.550	0.815	3.042	4.5	Hennig et al,[72] 2003
Nepal (PH)	66	13.2	0.589	0.888	2.673	35.7	Ruit et al,[73] 2007
Nepal (MSICS)	64	14.4	0.579	0.861	2.659	3.5	Ruit et al,[73] 2007
Nigeria	54	18.7	0.516	0.709	2.073	36.1	Alhassan et al,[75] 2000
Uganda	64	13.6	0.526	0.773	2.250	27.9	Waddell et al,[77] 2004
Zimbabwe	70	10.4	0.567	0.730	1.248	55.4	Killestein et al,[83] 1997
Developed Countries							
Australia	73	13.7	0.772	0.873	0.930	1043.8	Pager et al,[56] 2004
Australia	75	11.8	0.732	0.884	1.265	809.3	Kirkwood et al,[57] 2006
Canada	72	14.7	0.673	0.843	1.616	164.8	Norregaard et al,[59] 1998
Canada	72	14.7	0.667	0.843	1.671	159.3	Norregaard et al,[60] 2003
Canada	73	13.8	0.692	0.797	0.969	281.9	Noertjojo et al,[61] 2004
Denmark	74	14.0	0.678	0.840	1.499	530.4	Norregaard et al,[59] 1998
Denmark	73	14.6	0.678	0.840	1.534	509.5	Norregaard et al,[60] 2003
Finland	74	14.2	0.728	0.831	0.963	1000.8	Sarikkola et al,[31] 2004
Germany	62	21.4	0.681	0.889	2.369	473.0	Kohnen et al,[65] 1996
Israel	62	23.6	0.527	0.656	1.515	236.6	Leshno and Reuveni,[70] 1999
Malaysia (PH)	63	16.9	0.616	0.844	2.328	237.0	Loo et al,[16] 2004
Malaysia (ECCE)	66	14.8	0.527	0.812	2.727	175.3	Loo et al,[16] 2004
New Zealand	74	15.3	0.656	0.872	2.108	463.4	Riley et al,[74] 2002
Singapore	66	20.1	0.717	0.835	1.310	677.0	Saw et al,[29] 2002
Singapore	63	22.5	0.743	0.872	1.497	565.5	Wang et al,[76] 2005
Spain	69	17.0	0.605	0.799	1.991	311.2	Norregaard et al,[59] 1998
Spain	72	15.0	0.604	0.757	1.472	446.4	Castells et al,[33] 2001
Spain	70	16.2	0.605	0.799	1.945	326.0	Norregaard et al,[60] 2003
Sweden	76	13.7	0.694	0.913	1.999	289.1	Kobelt et al,[7] 2002
Sweden	76	13.5	0.661	0.783	1.111	521.9	Johannson and Lundh,[32] 2003
Sweden	72.5	16.0	0.828	0.913	0.847	637.4	Lundström et al,[34] 2006
United Kingdom	76	13.2	0.679	0.799	1.068	395.4	Desai et al,[78] 1999
United Kingdom	75	13.5	0.748	0.816	0.618	677.1	Tinley et al,[79] 2003
United Kingdom	77	12.6	0.696	0.834	1.198	358.5	Zaidi et al,[80] 2007
United States	73	14.4	0.712	0.861	1.394	1143.2	Norregaard et al,[59] 1998
United States	73	14.5	0.749	0.873	1.173	1356.1	Lum et al,[81] 2000
United States	72	15.0	0.708	0.861	1.470	1062.8	Norregaard et al,[60] 2003
United States	72	16.4	0.663	0.801	1.387	1083.2	Tobacman et al,[82] 2003

Abbreviations: ECCE, extracapsular cataract extraction; ICCE, intracapsular cataract extraction; LE, life expectancy; MSICS, manual small-incision cataract surgery; PH, phacoemulsification; QALY, quality-adjusted life-year.

[a] Cost is given in 2004 dollars. Mean age refers to the mean age of patients in each study. Preoperative and postoperative utility values are shown undiscounted. The QALY gain is the LE multiplied by the utility gain discounted at 3%. Cost utility values are discounted at 3% (costs and QALY gain) based on LE.

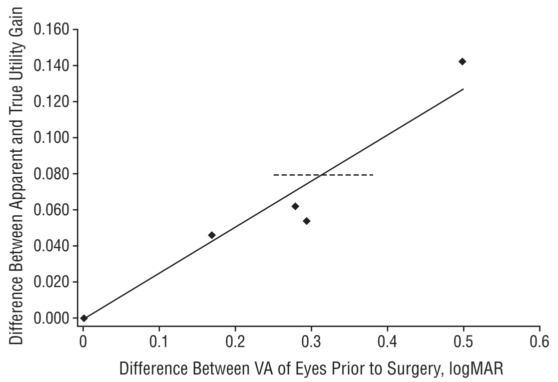

Figure 5. Linear regression plot of difference between preoperative visual acuity (VA) of operated-on and companion eyes and difference between apparent utility gain (calculated using preoperative operated-on eye VA data) and true utility gain (calculated using preoperative companion eye VA data). The horizontal bar represents maximum possible utility gain estimated from second-eye cataract surgery when the first eye has normal sight (Brown et al[10]).

However, the difference in postoperative VA values between countries is much smaller, suggesting that, on average, the outcomes of cataract surgery in developing countries are starting to approach those in developed countries (Figure 3). In terms of cost utility, this means that for cataract surgery, a high threshold of VA (poorer preoperative vision) will ensure a more cost-effective intervention.

In this study, we used life expectancy tables for each country matched as closely as possible to the year the cataract surgery study was undertaken, using the mean age of the study cohort as the reference age for starting the benefit. This approach provides the most accurate results possible, since duration of cataract surgery is expected to last over the remaining years of the patient.[89] Over the next 10 to 15 years, patients may be expected to live longer in developing countries, and thus, the cost utility of cataract surgery ought to increase, but against this change, one must consider the possibility that the threshold VA at which cataract surgery is performed may also increase, as has happened in developed countries. For example, our analysis showed that an increase of 10% in preoperative VA (better vision) and 10% decrease in postoperative VA (poorer outcome) increased cost utility by 26%. Conversely, if surgery in developing countries is improved so that the postoperative VA is increased by 10%, considerable gains in cost utility are possible.

The costs used in our studies generally covered only the costs of basic surgery provided by the private, government, or nongovernment organization carrying out the surgery (ie, provider costs, proportional facility overheads, IOL cost, anesthesia costs, postoperative medicine costs, and cost of 1 follow-up visit); they do not include costs of complications or adverse events or out-of-pocket expenses, especially costs related to healing and caregiving. However, the cost basis in some developing countries is very difficult to ascertain and thus may not be comparable with those from the countries in which the costs are meticulously specified.

Table 4. Sensitivity Analysis[a]

Factor	Cost Utility (Change %)
Life expectancy, ±2.5 y	216-334
Visual acuity change, ±10%	220-334
Discount, 0%-5%[b]	330-227
Cost, +25%	330
Cost, ×300%	791

[a] Base case is cost utility of $264/quality-adjusted life-year. Cost cases are discounted at 3%.
[b] For 3% compared with 0%, the decrease in the cost utility figure is 20%.

For example, average costs (undiscounted) incurred by cataract surgery alone in the United Kingdom were about $620 in 2004 dollars. However, a comprehensive cost analysis carried out by Sach et al[90] demonstrated that the cost difference between the control and experimental arms of their randomized controlled trial of cataract surgery was £2004 in 2006, which equates to $3461 in 2004 dollars. This cost is approximately 5.6 times the figure of $620. In developing countries, we do not know what the comparable differential is since there is a paucity of data on this subject, although it might be less compared with developed countries, as many of the factors that go into detailed cost calculations will likely be absent.

The World Health Organization has suggested benchmarks for the cost-effectiveness of interventions based on regions.[91] When the cost-effectiveness value is below the gross domestic product per capita, the intervention is considered very cost-effective; values of 1 to 3 times the gross domestic product are considered cost-effective, and values more than 3 times the gross domestic product are not considered cost-effective. On this basis, the cost utility of cataract surgery in all the developing countries analyzed in this study easily meets the World Health Organization definition of very cost-effective, no matter how it is calculated, in many instances by a large margin.

There are limitations to our study. Calculations of cost utility were predicated on accurate costs and VA data and the quality of both varied considerably in the studies we used. For some countries, such as India, where there was a wealth of data, averaging the results from many studies will tend to provide more accurate estimates for the country as a whole. However, there is likely to be more error in the case of a single study used to represent 1 country. In addition, the development of correction factors to account for the poorer correlation of VA data with utility values in the worse-seeing eye was based on data from only a few studies, with errors that are hard to estimate. Last, we focused on direct cataract surgery costs because there is little information available on other costs in developing countries. The realistic cost utility of cataract surgery is therefore higher (eg, cost per QALY gained) than we have presented, although we do not believe this materially affects our conclusions. On the other hand, the strengths of our study include the fact that we used a regression equation to derive utility values from VA data and local life expectancy tables to estimate the length of benefit duration. Further, we have explored as many variables as possible to determine their likely impact on cost utility.

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