Cost-effectiveness of cataract surgery in a public health eye care programme in Nepal

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Presented is an assessment of the cost-effectiveness of cataract surgery using cost and services data from the Lumbini Zonal Eye Care Programme in Nepal. The analysis suggests that cataract surgery may be even more cost-effective than previously reported. Under a "best estimate" scenario, cataract surgery had a cost of US$ 5.06 per disability-adjusted life year (DALY). This places it among the most cost-effective of public health interventions. Sensitivity analysis indicates that cataract surgery remains highly cost-effective even under a very pessimistic set of assumptions. The estimated mortality rates of those who receive surgery and of those who do not are among the variables that most influence the cost per DALY.

Introduction

Programme planners and policy-makers are turning increasingly to cost-effectiveness assessments to guide the allocation of health care resources. The World Bank, for example, has systematically applied cost-effectiveness criteria to establish priorities for health spending in low-income countries. In 1993 it included cataract surgery in the "most highly cost-effective" category of health interventions (*1*, *2*). This article presents a re-assessment of the cost-effectiveness of cataract surgery using cost and services data from the Lumbini Zonal Eye Care Programme in Nepal. The findings suggest that cataract surgery may be even more cost-effective than previously believed (cataract surgery was found to have a cost per "disability-adjusted life year" (DALY) of US$ 5.06). This is in the same range of cost-effectiveness as other well-accepted public health interventions.

The cataract programme run by Seva, a US/Canadian nongovernmental organization, is used as the basis for the cost and benefits data presented here. Since 1985, Seva has been running a comprehensive blindness programme serving the 2 million people living in the Lumbini Zone, south-central Nepal. Besides supporting a base eye hospital, Seva's programme emphasizes field-based services including eye camps, screening camps, district-level clinics, and the training of village primary eye-care volunteers.

Cataract surgery in the Lumbini Eye Care Programme is performed on an outpatient basis under local anaesthetic followed by 7 days of observation at the eye hospital or eye camp. Typically patients underwent extracapsular cataract removal followed by insertion of a posterior chamber intraocular lens. A significant percentage of patients underwent intracapsular cataract extraction and received standard +10 dioptre cataract spectacles. Since intraocular lenses were donated to the programme, for cost purposes it was assumed that all patients received aphakic spectacles.

Methods

Cost-utility analysis is a specific approach that is useful for determining the contribution of an intervention to both the length and quality of life (*3*). The method depends on assigning weights to different health states (0 for death, through 1.00 for perfect health) (*4*, *5*). These weights are then multiplied by the number of years that the health state exists, and discounted to the present. The final figure expressed in DALYs summarizes the value of the health state multiplied over the number of years that health state is expected to persist. By subtracting the discounted number of DALYs the patient would experience with no intervention from the number of discounted DALYs produced by an intervention, the net DALYs resulting from the intervention are obtained. Division of the net DALY by the discounted cost of the intervention yields the cost per DALY. The latter value expressed in dollars per DALY can then be used to compare the value of alternative interventions. In general, the cost of one net DALY can be calculated using the expression shown in Fig. 1, where N = remaining years of life; r = discount rate; m_1 = mortality rate given option 1, and m_2 = mortality rate given option 2.

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Fig. 1. **General expression for calculating cost-utility, expressed as US$ per DALY.**

$$\text{Cost-utility of intervention} = \frac{\sum_1^N \frac{\text{Cost}}{(1+r)^n}}{\sum_1^N \frac{\text{Utility of health state: option 1}}{(1+r)^n(1+m_1)^n} - \sum_1^N \frac{\text{Utility of health state: option 2}}{(1+r)^n(1+m_2)^n}} = \text{US\$ per DALY gained}$$

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Estimating the value of the parameters

In the analysis, "option 1" was cataract extraction and "option 2" no cataract extraction. On the basis of empirical data from ratings from the general public, experts and patients, Sackett & Torrance assigned a utility value of 0.39 to a lifetime of blindness. Other utility values from this seminal study are presented in Table 1, for comparison purposes (*6*).

The length of expected life following intervention and the length of expected life with no intervention are key parameters for estimating the utility of cataract surgery. The annual 1980 mortality rate among nonblind Nepalese for a population with the same age–sex structure as the cataract backlog is 6.7% (*7*). There is evidence that the blind in India and Nepal have higher mortality rates than the nonblind. According to the Nepal Blindness Survey, 5-year survival rates of less than 50% have been reported in some areas (*8*). A 1992 longitudinal study of a cohort of 1020 people aged 40–64 years in central India with cataract reported a mortality rate that was double that of the normal population (*9*). In the absence of specific data on the survival of individuals with cataract in Nepal, those who received no surgery were assumed to have a mortality rate of 0.134 (double that of the noncataract population of the same age). Furthermore, it was assumed that those who received surgery had the same mortality rates as those who had never had cataract. There is evidence that the mortality rate for cataract patients aged under 75 years in the USA may be higher than that in the general population; this risk declines progressively and becomes insignificant after 75 years of age (*10*).

Although previous studies have assigned a utility value of 1.0 to successful bilateral cataract surgery (*2*), this may be an overestimate for Nepal. In most public health cataract programmes in low-income countries, patients receive standard +10 dioptre cataract spectacles following surgery, rather than spectacles that match their true refractive error; they are therefore likely to have poor visual acuity after surgery. Nationwide follow-up data in Nepal shows that only 23.4% of cataract patients had visual acuity of 6/18 or better 6–18 months after surgery (E. Marseille, unpublished data, 1989). Over time visual acuity may decline further as patients lose or break their spectacles. In a 1–10-year follow-up study of aphakic patients in Karnali Zone, Nepal, investigators found that 25% had lost or broken their spectacles and 31% were wearing scratched or repaired spectacles (*11*). Data from the Nepal Blindness Survey also indicated that there were high rates of blindness among those with aphakia because of lost or broken glasses (*12*).

This suggests that the effective vision experienced by cataract patients in developing countries may deviate significantly from the theoretical efficacy of cataract surgery with intraocular lens implantation or good spectacle correction. Even with spectacle-corrected visual acuity of 20/20, individuals with aphakia suffer from a variety of other visual defects. In the present study, a utility value of 0.87 has been assigned to aphakia, making no distinction between bilateral and unilateral aphakia. This lies between the utility states associated with mild angina and with kidney transplant (see Table 1) and is similar to the value of 0.90 for restored sight that was

Table 1: **Reported utility of various states of health**

Healthy	1.00
Life with menopausal symptoms	0.99
Mild angina	0.90
Kidney transplant	0.84
Physical limitation with some pain	0.67
Deaf, dumb or *blind*	0.39
Dead	0
Confined to bed with severe pain	<0

Table 2: **Total and per patient costs for cataract surgery, Lumbini Eye Care Programme, Nepal, 1991–93**

	Total cost (US$)	Cost per patient (US$)	% of in-country costs	% of total costs
Marginal cost (drugs and supplies)	28660	3.01	18.4	13.9
Recurring in-country costs (Includes marginal costs)	132295	13.91	85.2	64.1
Capital costs	23052	2.42	14.8	11.2
Total in-country costs	155347	16.33	100.0	75.2
Recurring USA costs[a]	51187	5.38		24.8
Grand total	206534	21.71		100.0

[a] Non-capital expenditures incurred by Seva in the USA in support of the Lumbini Eye Care Programme.

used in a previous evaluation of the utility of cataract surgery.[a] Finally, only about 90% of individuals who undergo cataract extraction in Nepal regain sight in the operated eye (E. Marseille, unpublished data, 1989). The expected utility derived from the surgery is therefore discounted by this factor.

Data on the cost of cataract surgery were obtained from the accounting records of the Lumbini Eye Care Programme for the period 1991–93 and from Seva's financial records in the USA. Line item expenditures were apportioned to the cataract component of the Lumbini Eye Care Programme and divided by the number of operations conducted. The marginal cost of cataract surgery was US$ 3.01 per case; recurring in-country costs were US$ 13.91 per case; capital costs were US$ 2.42 per case; and Seva's administrative costs in the USA added another US$ 5.38 per case, for a total cost corresponding to US$ 21.71 (*13*), (see Table 2).

Results

Incorporation of the above values into the equation shown in Fig. 1 and using a discount rate of 3% yields a net increase of 4.29 discounted DALYs over 15 years. At an average cost of US$ 21.71 per operation, cataract surgery in Nepal costs US$ 5.06 per DALY (see Table 3). This suggests that cataract surgery is highly cost-effective relative to other public health investments. For example, Prost & Prescott found that river blindness control in Upper Volta cost US$ 150 per discounted DALY, which compared favourably to investments in measles immunization in Africa (*14*). In developing countries, in general, immunization against poliomyelitis plus diphtheria–pertussis–tetanus (DPT) costs US$ 20 per DALY in high-mortality environments and US$ 40 per DALY in low-mortality environments (*15*). With a cost per DALY of only US$ 1.00–3.00, chemotherapy for tuberculosis is one of the most cost-effective of all health interventions (*16*). Cataract surgery, while less cost-effective than this, is still among the few interventions that costs less than US$ 10 per DALY saved.

Sensitivity analysis

There are uncertainties about the values of most of the variables that were used to calculate the cost-utility for cataract surgery. For example, the value used for the utility for blindness in the present study (0.39) is based on data from industrialized countries; in Nepal or other low-income countries a different value may apply. Similarly the mortality rate among unoperated individuals with cataract may differ from the best estimate of 0.134%. Because of these uncertainties, a sensitivity analysis was conducted to determine how robust the findings of this analysis are; the results are shown in Table 3.

In the "best estimate" scenario the cost of cataract surgery is US$ 21.71 per case. For the Lumbini Zonal Eye Care Programme in Nepal, this includes the US$ 5.38 in administrative and overhead costs assumed by the Seva Foundation in the USA. If the programme could be maintained at the same level of productivity without external aid, the per-case cost would fall to US$ 16.33. This is the cost used in the "high estimate" scenario, which also assumes a low discount rate (1% per year), high rates of surgical success (95%), high utility for operated patients (0.95 DALYs per year), and a high level of mortality among the unoperated cataract blind (16.8% per year). Since the simultaneous occurrence of these values is very unlikely, the US$ 2.57 per discounted DALY produced can be considered to be near the theoretical upper bound of the cost-effectiveness for cataract surgery with current technologies.[b]

[a] **Drummond EF.** Financial incentives to change behavior toward health technology. Paper prepared for: *EC Workshop on regulatory mechanisms concerning expensive health technology, London, April 22–25, 1986.*

[b] This assumes that marginal costs equal average costs. In situations where marginal costs are lower than average costs cataract services could become still more cost-effective. These situations may arise where there is unused capacity within an existing programme, e.g., unused beds in a hospital or ophthalmic staff working less than full time.

Table 3: **Cost-utility of cataract surgery under three scenarios**

Parameter	Scenario		
	Low estimate	Best estimate	High estimate
Mortality rate for unoperated cataract blind	0.100	0.134	0.168
Mortality rate for operated cases	0.067	0.067	0.067
DALY for blind	0.50	0.39	0.39
DALY for operated cases	0.80	0.87	0.95
Chance of having sight in operated eye after surgery	0.85	0.9	0.95
Discount rate	5%	3%	1%
Average cost per cataract operation (US$)	40.00	21.71	16.33
Cost per DALY (US$)	20.53	5.06	2.57

The "low estimate" scenario reflects a set of conditions that do not exist in Nepal but which might apply to other countries. These include a cost of US$ 40.00 per case, a discount rate of 5% per year, a relatively low rate of surgical success (85%), a higher utility for blindness (0.5 DALYs per year), a low utility for sight restoration (0.80 DALYs per year), and a relatively low rate of mortality among the unoperated cataract blind (10% per year). Such unfavourable circumstances are also unlikely to occur in combination. The US$ 20.53 per DALY can therefore be considered the lower bound of the range of possible cost-effectiveness values for cataract surgery in low-income countries. Even this high cost per DALY is comparable to the US$ 20 per DALY for poliomyelitis + DPT immunization in high-mortality environments. This suggests, therefore, that even under very unfavourable conditions, cataract surgery is likely to be as cost-effective as most of the widely accepted and employed interventions in the public health armamentarium.

There is much debate about the proper choice of discount rates for cost-effectiveness analysis. Higher rates tend to diminish the calculated value of future benefits. Following World Bank practice, a rate of 3% was taken in the "best estimate" scenario (*17*). This represents the pure "social rate of time preference"; however, Javitt used a discount rate of 5% for cataract in developing countries (*2*). Applying this rate to the "best estimate" scenario increases the cost per DALY from US$ 5.06 to US$ 5.68. Selection of discount rates based on expected rates of growth in consumption produces discount rates as high as 10% (*18*), and incorporating this rate into the "best estimate" scenario yields a cost per DALY of US$ 7.30. These examples show that while the cost-effectiveness of cataract surgery is sensitive to the choice of discount rates, it remains highly cost-effective even if high rates are used.

Discussion

Conditions affecting cost-effectiveness vary from country to country. These include the cost of drugs and supplies, personnel costs, mortality rates, and cataract prevalences. Nepal's poor transportation and communication infrastructure combined with difficult terrain may tend to make programme expenses higher than in many other countries. On the other hand, the low cost of Indian-made supplies and equipment tends to keep costs lower than they might be in other developing country eye care programmes. Per-case costs may also increase in areas with lower cataract prevalences since more resources would need to be devoted to case-finding and to transportation. The prevalence of cataract blindness in Nepal (0.54%) is typical or even somewhat low for a developing country. The rate in Botswana is 0.63%, in Indonesia 0.80%, and in Pakistan 1.34%.[c] Overall, this suggests that Nepal is fairly typical of low-income countries as far as the conditions that affect the cost-effectiveness of cataract surgery are concerned.

The cost-effectiveness of a public health cataract surgery programme is also sensitive to the mortality rate of the operated cases. Every 10% decrease in the mortality rate (e.g., a drop from 0.60% to 0.54%) produces a 10% reduction in the cost per DALY. All else being equal, countries with higher than average life expectancy among those over 50 years of age can expect to have higher levels of cost-effectiveness from cataract surgery programmes. This suggests that over time, as adult life expectancy increases in keeping with long-term development trends, cataract surgery will become even more cost-effective.

By putting benefits on a common basis (DALYs), cost-effectiveness analysis permits com-

[c] *Available data on blindness (update 1987).* Unpublished document WHO/PBL/87.14, Geneva, World Health Organization 1987.

parison of programmes within the health sector. However, such an approach does not always take into account the full range of benefits generated by a programme. In the case of cataract surgery, these include two important effects not captured by cost-effectiveness analysis. These are the value of the economic activities that the patient can resume following surgery, and the economic value of the labour previously required to care for a blind family member. Future research could estimate dollar costs for these two factors in order to arrive at a comprehensive cost–benefit valuation for cataract surgery. This would permit comparisons of investments in cataract surgery with competing investment options not only in the health sector, but in others also.

Conclusion

Modern ophthalmic technology can be used to remove cataracts safely and effectively in low-income countries, even in remote rural areas. Recent studies have shown that its cost-effectiveness compares favourably with most other public health interventions. With a "best estimate" cost of only US$ 5.06 per DALY, the data from Nepal presented here suggest that removal of cataracts may be among the most cost-effective of all interventions. This result is somewhat surprising since the procedure requires an ophthalmologist or other highly trained ophthalmic personnel, relatively expensive supplies and equipment, and because cataract is a disease of advancing age in the overwhelming majority of cases. Its high cost-effectiveness stems from other characteristics of the procedure. First, operations for cataract surgery can be carried out in only about 30 minutes; such operations can be performed on a mass basis in eye camps or at well-attended base hospitals. Second, cataract surgery is almost always successful, and generates a large net increase in utility per operation.

In view of their high level of cost-effectiveness, the initiation of new cataract programmes and the expansion of existing ones should be given high-priority consideration in the planning of health services in low-income countries.

Résumé

Rapport coût-efficacité du traitement chirurgical de la cataracte dans le cadre d'un programme de soins ophtalmiques au Népal

Les techniques ophtalmologiques modernes permettent un traitement chirurgical sûr et efficace de la cataracte dans les pays à faible revenu, même dans les régions rurales isolées. La présente étude, fondée sur les données relatives aux coûts et services du programme de soins ophtalmiques de Lumbini (Népal), montre également que la chirurgie de la cataracte présente un rapport coût-efficacité très favorable dans ces circonstances. En appliquant un scénario fondé sur la "meilleure valeur estimée", on arrive à la conclusion que la chirurgie de la cataracte a un coût par année de vie corrigée de l'incapacité (disability-adjusted life year : DALY) de US $5,06, ce qui tend à montrer que cette intervention a un rapport coût-efficacité plus favorable qu'on ne le pensait jusqu'ici et qu'il s'agit en fait d'une des interventions de santé publique les plus "rentables" qui puissent être pratiquées dans les pays à faible revenu.

Une approche "coût-utilité" a été adoptée pour mesurer le rapport coût-efficacité de la chirurgie de la cataracte au Népal. Les données relatives au coût de l'intervention ont été compilées à partir des documents comptables du programme de soins ophtalmiques de la Fondation Seva à Lumbini sur une période de deux ans (1991–93). Pour chaque poste de dépenses, la fraction attribuable à l'élément "cataracte" du programme a été évaluée et divisée par le nombre d'interventions effectuées. Le coût marginal de chaque intervention a été trouvé égal à US $3,01; les coûts récurrents au niveau local ont été de US $13,91 par cas, les coûts d'investissement de US $2,42 et les coûts administratifs de Seva aux Etats-Unis se sont élevés à US $5,38, ce qui représente au total US $21,71 par cas.

Dans une analyse coût-utilité, le calcul des avantages dépend du poids attribué aux différents états de santé. Ces poids sont ensuite multipliés par le nombre d'années que dure l'état de santé en question, puis actualisés. Le résultat est exprimé en années de vie corrigées de l'incapacité (DALY). En soustrayant le nombre actualisé de DALY que vivrait le patient en l'absence d'intervention du nombre actualisé de DALY produit par l'intervention, on obtient le nombre net de DALY gagné grâce à l'intervention. Ce chiffre peut ensuite être divisé par le coût actualisé de l'intervention pour calculer le coût par DALY. Le résultat, exprimé en dollars par DALY permet de comparer la valeur des différentes interventions possibles.

A partir d'évaluations empiriques effectuées par le grand public, les experts et les patients, une "valeur d'utilité" de 0,39 a été attribuée à une vie entière de cécité. Selon le scénario de la meilleure valeur estimée, le taux annuel de mortalité pour les aveugles non opérés de la cataracte est de 13,4%, contre 6,7% pour ceux qui ont été opérés.

Si l'on applique un taux d'actualisation de 3% sur 15 ans, le traitement chirurgical de la cataracte entraîne une augmentation nette de 4,29 DALY; en divisant le coût d'une intervention (US $21,71) par ce chiffre, on arrive à un coût de US $5,6 par DALY. Une analyse de sensibilité montre que la chirurgie de la cataracte présente un rapport coût-efficacité très favorable, même si l'on part d'hypothèses très pessimistes.

Ces résultats tendent à montrer que, par comparaison avec d'autres utilisations des ressources en matière de santé, le traitement chirurgical de la cataracte se traduit par un bénéfice net important. Par exemple, une étude a montré que le coût actualisé du programme de lutte contre l'onchocercose en Haute-Volta était de US $150 par DALY, valeur qui, elle-même, se compare favorablement aux sommes consacrées à la vaccination contre la rougeole en Afrique. De façon générale, dans les pays en développement, le coût de la vaccination contre la poliomyélite, la diphtérie, la coqueluche et le tétanos est de US $20 par DALY dans les zones à forte mortalité et de US $40 par DALY dans les zones à faible mortalité.

Compte tenu du rapport coût-efficacité favorable du traitement de la cataracte, une priorité élevée devrait être accordée aux programmes actuels et futurs dans ce domaine lors de la planification des services de santé dans les pays à faible revenu.

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