Cost-effectiveness analysis of cataract surgery: a global and regional analysis

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Objective To estimate the population health effects, costs and cost effectiveness of selected cataract surgery interventions in areas of the world with different epidemiological profiles.

Methods Effectiveness estimates are based on a review of the literature taking into account factors such as operative failure, complications and patient non-compliance. A population model was applied to follow the lifelong impact on individuals having cataract surgery. Costing estimates are based on primary data collected in 14 epidemiological subregions by regional costing teams and on a literature review. Costings were estimated for different geographical coverage levels using non-linear cost functions.

Findings Intra- and extra-capsular cataract surgeries are cost-effective ways to reduce the impact of cataract-blindness. Extra-capsular cataract surgery is more cost-effective than intra-capsular surgery in all regions considered. Providing extra-capsular cataract surgery to 95% of those who need it (95% coverage level) would avert over 3.5 million disability-adjusted life years (DALYs) per year globally. The cost-effectiveness ranges from 57 International dollars (I$) per DALY in the WHO South-East Asia Region where there is high overall child and adult mortality to I$ 2307 per DALY in the WHO Western Pacific Region where there is low overall child and adult mortality.

Conclusion Extra-capsular surgery for cataracts at a high level of coverage is the most cost-effective way of restoring sight in all epidemiological subregions considered. Analysts from countries within a region are encouraged to further contextualize the results based on their own country's specific parameters.

Keywords Cataract extraction/economics/complications; Lens implantation, Intraocular/complications; Eyeglasses/utilization; Treatment outcome; Patient compliance; Disability evaluation; Cost-benefit analysis; Cost of illness; Comparative study; Review literature; Meta-analysis (*source: MeSH, NLM*).

Mots clés Extraction cataracte/économie/complication; Implantation intraoculaire lentille/complication; Verres correcteurs/utilisation; Evaluation résultats traitement; Observance prescription; Evaluation incapacité; Analyse coût-bénéfice; Coût maladie; Etude comparative; Revue de la littérature; Méta-analyse (*source: MeSH, INSERM*).

Palabras clave Extracción de catarata/economía/complicaciones; Implantación de lentes intraoculares/complicaciones; Anteojos/utilización; Resultado del tratamiento; Cooperación del paciente; Evaluación de la incapacidad; Análisis de costo-beneficio; Costo de la enfermedad; Estudio comparativo; Literatura de revisión; Meta-análisis (*fuente: DeCS, BIREME*).

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Introduction

Cataracts are a major cause of blindness and of severe visual impairment leading to bilateral blindness in an estimated 20 million people worldwide. In developing countries 50–90% of all blindness is caused by cataracts (*1*).

A cataract is a clouding of the lens of the eye that causes loss of vision. Although cataracts result from many conditions, the most frequent cause is the natural ageing process. Other causes include injury, chronic eye disease and other systemic diseases, such as diabetes (*2*). Cataracts can take from a few months to several years to develop and can affect both eyes at the same time, but they often develop at different rates. Sometimes the cataract stops developing in its early stages and vision is only slightly impaired. But if it continues to develop, vision is impaired, and treatment is necessary. Surgery to remove the opacified lens is the only effective treatment for cataracts. Neither diet nor medications have been shown to stop cataract formation. There are several possible approaches for the surgical extraction of cataracts. In this paper we evaluate the cost effectiveness of two different surgical procedures delivered to 50%, 80% or 95% of those who need surgery.

Cost-effectiveness analysis can be undertaken in many ways, and there have been several attempts to develop methodological

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guidelines to make results more comparable. WHO has developed a standardized set of methods and tools that can be used to analyse the societal costs and impact on the health of the population of current and new interventions at the same time (*3*, *4*). The WHO-CHOICE (CHOosing Interventions that are Cost-Effective) project is intended to provide regularly updated databases on the costs and effects of a full range of interventions to promote health and prevent disease, and to cure and rehabilitate. Additional information on the project is shown in Box 1 (web version only, available at: http://www.who.int/bulletin). Adopting this standardized approach to generalized cost-effectiveness analysis allows comparisons to be made among a range of interventions relating to cataracts as well as with interventions for other major health problems.

Methods

Regions

It would be desirable to evaluate all possible combinations of interventions for every country in the world. In the case of some of the larger countries, it would be desirable to evaluate these combinations at a subnational level. No country has yet been able to do this, and many countries do not have the technical capacity to evaluate even a few interventions. At the other extreme, global estimates of an intervention's cost effectiveness are of little use to any specific country.

This study provides information on the costs and health effects of cataract surgery at the subregional level in different parts of the world. Regions are grouped by geographical proximity and epidemiological similarity (Box 2). These can then be further contextualized to the country level.

Interventions

The aim of cataract surgery is to rehabilitate blind or visually impaired people by restoring their sight to normal or as near to normal as possible. This analysis distinguishes between two types of surgical intervention. Intra-capsular cataract extraction, using aphakic glasses (ICCE-AG), is a technique where the whole lens is removed from the eye. After surgery special eyeglasses are provided to patients to restore sight. In extra-capsular cataract extraction with implantation of a posterior chamber intraocular lens (ECCE-PC-IOL), the lens and the front portion of the capsule are removed and then replaced with an artificial lens.

Box 2. **Regions used in this study**

Region	Mortality stratum[a]	Countries included
Africa	D	Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial, Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Togo
Africa	E	Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
Region of the Americas	A	Canada, United States of America, Cuba
Region of the Americas	B	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, El Salvador, Grenada, Guyana, Honduras, Jamaica, Mexico, Panama, Paraguay, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela
Region of the Americas	D	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru
Eastern Mediterranean Region	B	Bahrain, Cyprus, the Islamic Republic of Iran, Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates
Eastern Mediterranean Region	D	Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, Sudan, Yemen
European Region	A	Andorra, Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland, United Kingdom
European Region	B	Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Poland, Romania, Slovakia, Tajikistan, the Former Yugoslav Republic of Macedonia, Turkey, Turkmenistan, Uzbekistan, Yugoslavia
European Region	C	Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine
South-East Asia Region	B	Indonesia, Sri Lanka, Thailand
South-East Asia Region	D	Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Maldives, Myanmar, Nepal
Western Pacific Region	A	Australia, Japan, Brunei Darussalam, New Zealand, Singapore
Western Pacific Region	B	Cambodia, China, Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Lao People's Democratic Republic, Marshall Islands, Malaysia, Mongolia, Nauru, Niue, Palau, Papua New Guinea, Philippines, Republic of Korea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Viet Nam

[a] A = Regions with very low adult mortality and low child mortality; B = Low adult mortality and low child mortality; C = High adult mortality and low child mortality; D = High adult mortality and high child mortality; E = Very high adult mortality and high child mortality.

We evaluated both procedures for 14 epidemiological subregions, except for the four areas where ICCE-AG is not used (Box 2).

Modelling health effects on the population

To assess the impact of cataracts on population health, a population model was developed to simulate the life span of individuals in a population. Population health is expressed as the number of healthy years lived (HYL) and the difference in HYL as disability-adjusted life years (DALYs) that are averted as a result of the intervention. The model allows individuals to be categorized into one of three mutually exclusive health states: healthy, cataract-blind and dead.

Population health depends not only on the proportion of individuals who are blind but also on the disability weight that is associated with blindness. The flow of individuals from one state to another is similarly modelled for both the null scenario and the situation in which interventions are applied. Population models of the prevalence of cataracts were based on the regional global burden of disease data which include consistent prevalence and incidence data for 14 epidemiological subregions (*1*). The null scenario was derived from each model by setting the cataract remission rate in the model to 0 starting in the year 2000 to reflect the absence of cataract surgery. Analyses attach a disability weight of 0.6 to people who are blind (*1*).

Intervention effectiveness was modelled using the remission rate — that is, the number of people who are blind bilaterally because of cataracts and whose sight is restored in one eye (Table 1). WHO's definition of blindness was used.

Clinical studies report small variations in the effectiveness of ICCE-AG and ECCE-PC-IOL (*5*, *6*). WHO internal expert advisers assessed the real world effectiveness of these results, taking into account the occurrence of complications and non-compliance by patients. All estimates are explicitly presented as distributions around best estimates to reflect uncertainty, since most clinical studies typically involve only a limited follow-up period and do not capture these factors (Table 2).

After discussion with WHO's internal panel, the effectiveness of ICCE-AG and ECCE-PC-IOL were both estimated at 95%. Complications for both interventions were estimated to reduce effectiveness by 5%. Furthermore, non-compliance in terms of not wearing glasses (for whatever reason) may further reduce the effectiveness of ICCE-AG. In a survey in Nepal, it was found that for all bilaterally blind patients undergoing cataract surgery in a single eye, 27% were not wearing glasses at all after surgery because they did not own any, and at the time of the survey 82% were not wearing glasses, had broken glasses, or had dirty or scratched glasses (*7*). These data are confirmed by various WHO country reports showing that at 1–10 years after surgery, 18–69% of patients who have had surgery for cataracts do not wear glasses. For example, in Turkmenistan 35% of patients did not wear their glasses. The comparable percentages for other regions are: North Viet Nam, 69%; Punjab, 20%; Myanmar, 20–42%; and India, 18%. On the basis of this evidence, we assumed a reduction in effectiveness of 27–82% that was uniformly distributed.

The remission rate of cataracts is then estimated as: the natural log of (1 – [population effectiveness x the coverage of the intervention]) (see Table 1). Coverage rates for the interventions refer to the percentage of the cataract-blind population in each country that has the surgery over 10 years. These rates are arbitrarily defined at 50%, 80% and 95%.

Interventions were overlaid on the null scenario for the years 2000–10. The HYLs gained in each surgery scenario were then compared to the null scenario to estimate the DALYs averted.

Estimating costs

Costs covered in this analysis include programme-level costs associated with the intervention, such as administration and training, and patient-level costs, such as primary care visits. These costs were based on a standard ingredients approach developed by WHO-CHOICE to aid in costing interventions. The following components were included:

- Programme-level resource inputs used to produce an intervention at a level above that of the patient or facility providing the service, such as central planning, policy, training and administration functions. Estimated quantities of resources required to start and then maintain each intervention for 10 years at national, provincial and district levels were based on a series of evaluations made by experts in the different subregions. These were validated against the literature (categories of resource input included personnel, training, materials and supplies, media, transport, maintenance, utilities and capital);
- Patient-level resource inputs used to provide a given health care intervention (for example, hospital inpatient days, outpatient visits, medications, laboratory tests, etc.). Patient costs for cataracts include the costs of supplies and equipment related to the surgical procedures. Countries were clustered in three broad categories representing their utilization pattern for outpatient and inpatient visits, tests and compliance (Table 2).

Table 1. **Intervention effectiveness and coverage**

Type of surgery	Population coverage over 10 years	Surgical effectiveness[a]	Complications[a]	Patient compliance[b]	Effectiveness[c]	Remission[d]
ICCE–AG	50%	95% (75–100%)	5% (2–8%)	55% (27–82%)	49% (midpoint)	0.03 (midpoint)
ICCE–AG	80%	95% (75–100%)	5% (2–8%)	55% (27–82%)	49% (midpoint)	0.04 (midpoint)
ICCE–AG	95%	95% (75–100%)	5% (2–8%)	55% (27–82%)	49% (midpoint)	0.05 (midpoint)
ECCE–PC–IOL	50%	95% (75–100%)	5% (2–8%)	100%	90% (midpoint)	0.05 (midpoint)
ECCE–PC–IOL	80%	95% (75–100%)	5% (2–8%)	100%	90% (midpoint)	0.07 (midpoint)
ECCE–PC–IOL	95%	95% (75–100%)	5% (2–8%)	100%	90% (midpoint)	0.09 (midpoint)

[a] For uncertainty analysis, normal distributions are assumed for Surgical effectiveness and Complications. Ranges in brackets are 95% confidence intervals.
[b] For Patient compliance, a uniform distribution is assumed. Minimum and maximum values are reported in brackets.
[c] Effectiveness rate is found by multiplying Surgical effectiveness x (1 - Complications) x Patient Compliance.
[d] Annual remission hazard rate is estimated as –ln(1–(effectiveness x coverage/10)).

Table 2. **Resource utilization patterns**

	Group 1[a]	Group 2[b]	Group 3[c]	Type of distribution used in uncertainty analyses
Outpatient visits, 1st-level hospital				
ICCE-AG	2	2	3	Triangular, min and max values +/– 0.5 visit
ECCE-PC-IOL	2	2	3	Triangular, min and max values +/– 0.5 visit
Compliance after first outpatient visit				
ICCE-AG	60%	60%	NA[d]	Triangular, min and max values +/– 15%
ECCE-PC-IOL	60%	60%	100%	Triangular, min and max values +/– 15%
Inpatient days, 1st-level hospital				
ICCE-AG	2	2	NA	Triangular, min and max values +/– 1 day
ECCE-PC-IOL	2	2	1	Triangular, min and max values +/– 1 day

[a] Group 1 regions: Africa at mortality strata D and E; South-East Asia Region at stratum D; Western Pacific Region at stratum B.
[b] Group 2 regions: Region of the Americas at mortality stratum B; Eastern Mediterranean Region at stratum B; European Region at stratum C; South-East Asia Region at stratum B.
[c] Group 3 regions: Region of the Americas at mortality stratum A; European region at strata A and B; Western Pacific Region at stratum A
[d] NA, not applicable.

The number of outpatient and inpatient visits are based on a literature review. Resources used for ECCE-PC-IOL include an operation equipment kit, intraocular lenses and microscope. Resources used for ICCE-AG include a cataract equipment kit, a loupe and eyeglasses. Cataract surgery is assumed to be performed by a surgeon assisted by a nurse; and

- Unit costs of programme-level and patient-level resource inputs, such as the salaries of central administrators, the capital costs of offices and furniture, or the cost per inpatient and outpatient visit. Data were obtained from a review of the literature and supplemented by primary data from several countries or they were based on international catalogue prices for operation supplies and equipment. (For a full overview of all unit costs, see http://www.who.int/evidence/cea.).

Costs are reported in International dollars ($I) to facilitate more meaningful comparisons across regions. (For additional information about International dollars, see Box 3 web version only, available at: http://www.who.int/bulletin.) The base year is 2000. More details on health facility unit cost estimates are reported in Adam et al (*9*). A description of the estimates of the programmes' costs, including costing of various coverage levels as well as the scaling-up of costs to the level of WHO subregions, can be found in Johns et al (*10*).

This analysis reports the cost-effectiveness estimates of interventions that are done technically efficiently, using 80% capacity utilization as the norm. This ensures that the observed differences are due to the intrinsic characteristics of the intervention rather than the extent to which capital and labour have been utilized in the environment in which the interventions were evaluated. In comparison to studies describing the costs of interventions on the basis of the actual capacity utilization, this approach often results in much lower estimates of cost.

Full details of the methods used to generate these cost estimates, including the costing of various coverage levels as well as the scaling-up of costs to the level of the epidemiological subregions, are given in the WHO-CHOICE guidelines (*11*).

Cost-effectiveness ratios

The average cost-effectiveness ratios are calculated for each intervention by combining information on total costs with information on total health effects in terms of DALYs averted. All costs and effects are discounted at 3%.

Using a standardized approach, we have identified the set of interventions a region should purchase to maximize its health gain for different budgets. The order in which interventions would be purchased is called an expansion path and is based on the incremental costs and benefits of each intervention compared with the last intervention purchased.

The WHO Commission on Macroeconomics and Health defined interventions that have a cost-effectiveness ratio of less than three times the gross domestic product (GDP) per capita as cost effective (*12*). Based on this, three broad categories are defined here. Interventions that gain each year of healthy life (that is, a DALY averted) at a cost that is less than GDP per capita are defined as very cost effective. Those averting each DALY at a cost of between one and three times GDP per capita are cost effective. The remainder are not cost effective.

Uncertainty analysis

Probabilistic uncertainty analyses have been undertaken to consider how uncertainty about epidemiological, effectiveness and cost parameters translates into uncertainty about the cost-effectiveness ratio. The application of probabilistic uncertainty analysis with Monte Carlo simulations is described in full detail elsewhere (*13*). It requires that analysts assume some distributional form for costs and effects from which repeated samples are drawn to determine a distribution for the cost-effectiveness ratio.

Distributional forms for the parameters used in this analysis are defined in Table 1 and Table 2. The simple percentile method was used to estimate uncertainty intervals for cost-effectiveness ratios. In this approach, the 5th percentile and 95th percentile results were taken from Monte Carlo simulations in which all random variables were chosen simultaneously.

Results

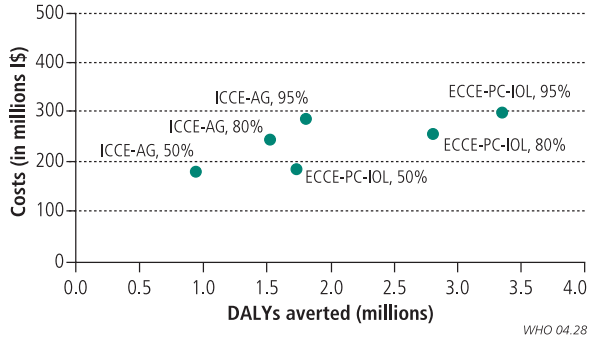
Table 3 provides the total annualized costs, total annual health effects in terms of DALYs averted, and the average cost-effectiveness ratios for each intervention. ECCE-PC-IOL is more cost effective than ICCE-AG in all regions considered. This is also illustrated in the expansion path for the region of Africa at mortality stratum D (Africa-D) (Fig. 1): ECCE-PC-IOL is both more effective and more cost effective than ICCE-AG and therefore dominates ICCE-AG.

Table 3. **Total costs, total effects and cost-effectiveness ratios of surgery for cataracts.** Costs are in International dollars

Type of surgery and population coverage	Region and mortality stratum[a]								
	Africa-D			**Africa-E**			**Region of the Americas-A**		
	Costs	DALYs[b] averted	CER[c]	Costs	DALYs averted	CER	Costs	DALYs averted	CER
ICCE–AG (50%)	I$ 178 152 508	939 307	I$ 190	I$ 194 196 131	871 392	I$ 223	–	–	–
ICCE–AG (80%)	I$ 244 491 401	1 514 435	I$ 161	I$ 264 221 988	1 404 937	I$ 188	–	–	–
ICCE–AG (95%)	I$ 285 777 631	1 805 353	I$ 158	I$ 323 774 534	1 674 820	I$ 193	–	–	–
ECCE–PC–IOL (50%)	I$ 185 404 117	1 725 787	I$ 107	I$ 201 364 634	1 601 007	I$ 126	I$ 78 238 817	90 989	I$ 860
ECCE–PC–IOL (80%)	I$ 256 127 347	2 800 852	I$ 91	I$ 275 732 664	2 598 341	I$ 106	I$ 107 271 053	147 670	I$ 726
ECCE–PC–IOL (95%)	I$ 299 635 492	3 350 208	I$ 89	I$ 337 491 506	3 107 976	I$ 109	I$ 137 110 649	176 634	I$ 776
	Region of the Americas-B			**Region of the Americas-D**			**Eastern Mediterranean-B**		
	Costs	DALYs averted	CER	Costs	DALYs averted	CER	Costs	DALYs averted	CER
ICCE–AG (50%)	I$ 177 071 623	505 943	I$ 350	I$ 41 245 070	132 053	I$ 312	I$ 112 429 783	362 226	I$ 310
ICCE–AG (80%)	I$ 213 006 986	815 726	I$ 261	I$ 56 200 709	212 907	I$ 264	I$ 134 174 731	584 013	I$ 230
ICCE–AG (95%)	I$ 247 293 612	972 424	I$ 254	I$ 68 192 935	253 806	I$ 269	I$ 152 242 225	696 199	I$ 219
ECCE–PC–IOL (50%)	I$ 175 198 028	929 567	I$ 188	I$ 40 370 539	242 620	I$ 166	I$ 111 374 223	665 516	I$ 167
ECCE–PC–IOL (80%)	I$ 210 008 703	1 508 634	I$ 139	I$ 54 794 876	393 759	I$ 139	I$ 132 483 738	1 080 094	I$ 123
ECCE–PC–IOL (95%)	I$ 243 725 337	1 804 536	I$ 135	I$ 66 517 703	470 990	I$ 141	I$ 150 226 297	1 291 943	I$ 116
	Eastern Mediterranean-D			**European Region-A**			**European Region-B**		
	Costs	DALYs averted	CER	Costs	DALYs averted	CER	Costs	DALYs averted	CER
ICCE–AG (50%)	I$ 163 319 311	804 919	I$ 203	NA[d]	NA	NA	NA	NA	NA
ICCE–AG (80%)	I$ 244 075 697	1 297 763	I$ 188	NA	NA	NA	NA	NA	NA
ICCE–AG (95%)	I$ 300 423 148	1 547 058	I$ 194	NA	NA	NA	NA	NA	NA
ECCE–PC–IOL (50%)	I$ 159 297 895	1 478 876	I$ 108	I$ 285 794 711	168 794	I$ 1 693	I$ 107 689 620	231 582	I$ 465
ECCE–PC–IOL (80%)	I$ 237 614 542	2 400 130	I$ 99	I$ 355 339 140	273 943	I$ 1 297	I$ 140 095 806	375 845	I$ 373
ECCE–PC–IOL (95%)	I$ 292 712 956	2 870 888	I$ 102	I$ 435 304 542	327 674	I$ 1 328	I$ 176 816 932	449 562	I$ 393
	European Region-C			**South-East Asia Region-B**			**South-East Asia Region-D**		
	Costs	DALYs averted	CER	Costs	DALYs averted	CER	Costs	DALYs averted	CER
ICCE–AG (50%)	I$ 96 373 500	279 596	I$ 345	I$ 90 542 192	782 508	I$ 116	I$ 368 926 580	3 406 866	I$ 108
ICCE–AG (80%)	I$ 133 119 296	450 791	I$ 295	I$ 141 989 313	1 261 630	I$ 113	I$ 515 255 872	5 492 857	I$ 94
ICCE–AG (95%)	I$ 158 336 992	537 386	I$ 295	I$ 174 376 918	1 503 985	I$ 116	I$ 650 255 189	6 548 014	I$ 99
ECCE–PC–IOL (50%)	I$ 94 390 409	513 702	I$ 184	I$ 87 273 603	1 437 701	I$ 61	I$ 390 079 751	6 259 428	I$ 62
ECCE–PC–IOL (80%)	I$ 129 943 382	833 709	I$ 156	I$ 136 741 553	2 333 305	I$ 59	I$ 549 177 219	10 158 690	I$ 54
ECCE–PC–IOL (95%)	I$ 154 538 300	997 231	I$ 155	I$ 168 116 486	2 790 957	I$ 60	I$ 690 608 004	12 151 203	I$ 57
	Western Pacific Region-A			**Western Pacific Region-B**					
	Costs	DALYs averted	CER	Costs	DALYs averted	CER			
ICCE–AG (50%)	NA	NA	NA	I$ 408 683 283	1 446 876	I$ 282			
ICCE–AG (80%)	NA	NA	NA	I$ 515 173 480	2 332 783	I$ 221			
ICCE–AG (95%)	NA	NA	NA	I$ 599 021 197	2 780 902	I$ 215			
ECCE–PC–IOL (50%)	I$ 96 909 558	31 360	I$ 3 090	I$ 417 668 029	2 658 341	I$ 157			
ECCE–PC–IOL (80%)	I$ 120 797 427	50 896	I$ 2 373	I$ 529 573 918	4 314 334	I$ 123			
ECCE–PC–IOL (95%)	I$ 140 464 459	60 878	I$ 2 307	I$ 616 138 875	5 160 543	I$ 119			

[a] See Box 1 for information on mortality strata.
[b] DALYs = disability-adjusted life years.
[c] CER = cost-effectiveness ratio.
[d] NA = not applicable.

Fig. 1. **Costs and effectiveness (in disability-adjusted life years (DALYs) averted) of two different types of cataract surgery at different levels of population coverage in Africa-D region (50%, 80%, 95%).** (ICCE–AG = Intra-capsular extraction using aphakic glasses. ECCE–PC–IOL = Extra-capsular cataract extraction with implantation of a posterior chamber intraocular lens.)



Moreover, the results also show that interventions that reach more people are always more cost effective than those that reach fewer people. This shows that economies of scale play a part in cost effectiveness (since the costs of administration and planning are relatively independent of the number of surgeries performed). ECCE-PC-IOL used with 95% coverage of the population would avert more than 3.5 million DALYs per year globally, with cost effectiveness ranging from I$ 57 per DALY in the South-East Asia Region at mortality stratum B to I$ 2307 per DALY in the Western Pacific Region at mortality stratum A.

The probabilistic uncertainty analysis included 5 000 random draws from predefined distributions, and it showed that the results were robust even when variations were introduced to the model's parameters. For example, ECCE-PC-IOL at 95% coverage in Africa-D has a mean cost-effectiveness ratio of I$ 89 per DALY, with the 5% to 95% percentile interval ranging from I$ 39 per DALY to I$ 148 per DALY (Table 4, web version only, available at: http://www.who.int/bulletin). Although the average cost-effectiveness ratios for different strategies could, in some cases, vary by a factor of 2 between the high estimates and the low estimates, the overall conclusion is that the range of interventions examined here would have attractive cost-effectiveness ratios. Also the findings regarding the relative cost effectiveness of different strategies remains largely unchanged.

Discussion

A number of studies have estimated the cost effectiveness of interventions in cataract control. This study is unique in that it evaluates the cost effectiveness of intra-capsular and extra-capsular cataract surgery in a framework of a single generalized cost-effectiveness analysis, and it does so for several regions. Extra-capsular surgery dominates intra–capsular surgery, and it can therefore be considered the best choice for cataract control. In all regions, extra-capsular surgery is very cost effective according to the criterion of the Commission on Macroeconomics and Health (*12*).

This analysis provides only broad indications of the cost effectiveness of cataract surgery. The results are presented for the regional level, using regional patterns of resource utilization and epidemiology. Although epidemiological patterns can be assumed to be relatively homogeneous between countries in a certain region, resource utilization patterns can be expected to vary. Decision-makers who wish to extrapolate the results to their own context should assess whether the quantities and costs of the various inputs are applicable to their setting. If so, they can estimate the cost effectiveness for their context. The models used to calculate costs and effects, including the raw input data, are available on the Internet at http://www.who.int/evidence/cea. This will allow the study's findings to be used to make decisions about resource allocation in a range of countries. Moreover, the assumption of technical efficiency (which is necessary to allow a fair comparison of the cost effectiveness of interventions across disease areas) may not be relevant to a specific decision-making context. To increase this study's relevance for policy-making, analysts are encouraged to put the results of this study into a context that represents the situation of their country.

The availability of surgeons to perform cataract surgery is another issue that must be addressed when interpreting results at the country level. The number of cataract surgeons is insufficient in many countries, especially if policy-makers wish to aim for a population coverage level of 95%. Cataract surgery rates fall short of this figure. For example, Lewallen & Courtright reported that coverage rates for cataract surgery in nine studies varied from 17% to 69% (*14*). We have shown that high coverage rates make cataract surgery more economically attractive. We believe more cataract surgeons should be trained.

The cost per surgery performed varies considerably by region. This may be caused by relative differences in resource utilization and price. Another reason is that programme-level resource inputs, such as costs of administration and planning beyond the patient-level, were assumed to be relatively independent of the number of cataract surgeries performed: regions with a relatively low number of cataract surgeries will thus have relatively high programme costs per surgery. (This is also the main reason why costs per surgery in the Western Pacific Region at mortality stratum A are higher than in the Region of the Americas at mortality stratum A.)

In general, the cost estimates in our study compare reasonably well with those reported in other studies (*15–23*) considering the large variations in methodologies used. For example, studies in India, Nepal and Mali show a range of costs from US$ 20–53 per cataract surgery (costs converted to US$ for the base year 2000), whereas we estimate costs in those regions to be in the range of US$ 24–68 (converted from International dollars using purchasing power parities). Our estimates tend to be relatively high because other studies typically have not included programme costs. As in the other studies, our cost estimates were restricted to health care costs because of the methodological problems involved in measuring the societal costs of a patient's time spent seeking care and undergoing care or societal gains in productivity (*11*).

At the individual level, ECCE-PC-IOL surgery decreases the disability weighting (for example, for a male aged 50 years old in Africa-D from 0.7 to 0.24). When the number of life-years that patients benefit from surgery is taken into account the effectiveness of surgery varies from 1 DALY to 3 DALYs per surgery. Our reported gains are in the same range as the 2 DALYs to 4 DALYs estimated by Javitt (*20*) and Marseille et al. (*24*), respectively. However, ours are on the conservative side. There are two main reasons for this difference. Firstly, we did not assume any case fatality associated with being blinded by cataract. Several studies carried out in Africa suggested mortality of 1.5–3.0, which is higher for people who are visually impaired or blind (*25*, *26*). But strong evidence for this rate is lacking. Secondly, our study applied a population model which allowed

for the precise calculation of DALYs averted whereas Javitt et al. (*20*) used a simpler approach. However, the effectiveness of the intervention was estimated on the basis of the number of cataract-blind people who are cured by surgery. This may overestimate the real health gains because it assumes full recovery of eyesight for all individuals who have a remission from being blind bilaterally, even though not all people may be blind bilaterally and some may benefit only slightly from cataract surgery.

Cost effectiveness is only one of the key inputs that affect the final decision about how to allocate scarce resources. Policy-makers have other concerns as well, such as reducing poverty and other inequalities. Another key concern for policy-makers is how different interventions can be incorporated into the health infrastructure of the country or how the infrastructure could be adapted to accommodate the desired strategies. The information presented here is only one of the critical inputs required to inform decision-making about efficient ways to reduce blindness caused by cataracts. ■

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Conflicts of interest: none declared.

Résumé

Chirurgie de la cataracte : analyse de coût-efficacité à l'échelle mondiale et régionale

Objectif Estimer les effets sur la santé de la population, les coûts et le rapport coût-efficacité de diverses interventions de chirurgie de la cataracte dans des régions ayant des profils épidémiologiques différents.

Méthodes Les estimations d'efficacité sont basées sur une revue de la littérature et tiennent compte de facteurs comme l'échec de l'intervention, les complications et la non-observance. Un modèle de population a été appliqué pour suivre l'impact sur toute la vie chez les sujets opérés de la cataracte. Les estimations de coût s'appuient sur les données primaires recueillies dans 14 sous-régions épidémiologiques par des équipes régionales ainsi que sur les données publiées. Les coûts ont été estimés au moyen de fonctions non linéaires pour différents taux de couverture géographique.

Résultats Les opérations intra- et extracapsulaires de la cataracte constituent un moyen d'un bon rapport coût-efficacité pour réduire l'impact de la cécité due à la cataracte. Dans toutes les régions considérées, le rapport coût-efficacité est meilleur pour la chirurgie extracapsulaire que pour la chirurgie intracapsulaire. En pratiquant une opération extracapsulaire sur 95 % des personnes qui en ont besoin (taux de couverture de 95 %), on éviterait chaque année, à l'échelle mondiale, plus de 3,5 millions d'années de vie ajustées sur l'incapacité (DALY). Le rapport coût-efficacité va de 57 dollars internationaux par DALY dans la Région OMS de l'Asie du Sud-Est, où la mortalité globale chez l'enfant comme chez l'adulte est élevée, à 2307 dollars internationaux par DALY dans la Région OMS du Pacifique occidental où la mortalité globale est faible.

Conclusion Dans toutes les sous-régions épidémiologiques considérées, l'opération extracapsulaire de la cataracte avec un taux de couverture élevé est à coût égal le moyen le plus efficace pour restaurer la vue. A l'intérieur de chaque région, les analystes des divers pays sont encouragés à replacer ces résultats dans leur contexte compte tenu des particularités locales.

Resumen

Costoeficacia de la cirugía de la catarata: análisis mundial y regional

Objetivo Estimar los efectos en la salud de la población, los costos y la costoeficacia de determinadas intervenciones de cirugía de la catarata en zonas del mundo que presentan distintos perfiles epidemiológicos.

Métodos Las estimaciones de la eficacia se basan en una revisión de la literatura que tiene en cuenta factores como el fracaso operatorio, las complicaciones y el incumplimiento por parte de los pacientes. Se aplicó un modelo de población para seguir el impacto de la operacion de catarata a todo lo largo de la vida en los individuos que se habían sometido a tal intervención. Las estimaciones de costos están basadas en datos primarios reunidos en 14 subregiones epidemiológicas por los equipos regionales de cálculo de costos y en una revisión de la literatura. Se usaron funciones de costos no lineales para estimar los costos asociados a distintos niveles de cobertura geográfica.

Resultados Las operaciones de cirugía intracapsular y extracapsular de la catarata son un instrumento costoeficaz para reducir el impacto de la ceguera por catarata. La cirugía extracapsular es más costoeficaz que la intracapsular en todas las regiones consideradas. Proporcionando cirugía extracapsular a un 95% de quienes la necesitan (cobertura del 95%) se evitarían más de 3,5 millones de años de vida ajustados en función de la discapacidad (AVAD) cada año a nivel mundial. La costoeficacia varía entre 57 dólares internacionales (I$) por AVAD en la Región de Asia Sudoriental de la OMS, donde hay una alta mortalidad general de niños y adultos, y I$ 2307 por AVAD en la Región del Pacífico Occidental de la OMS, donde hay una baja mortalidad general de niños y adultos.

Conclusión La cirugía extracapsular de la catarata, asegurando un alto nivel de cobertura, es la alternativa más costoeficaz para restablecer la vista en todas las subregiones epidemiológicas consideradas. Se alienta a los analistas de los países de cada región a que sigan contextualizando los resultados incorporando los parámetros específicos de su país.

ملخص

تحليل مردودية جراحة الساد (الكاتاراكت): تحليل عالمي وإقليمي

الغرض: تقدير تكاليف ومردودية مجموعة منتقاة من مداخلات جراحة الساد (الكاتاراكت) في مناطق من العالم ذات مرتسمات وبائية مختلفة، وتقدير تأثيرات هذه المداخلات على صحة السكان.

الطريقة: ترتكز تقديرات فعالية الجراحة على مراجعة الدراسات ذات الصلة، مع الأخذ في الحسبان بعض العوامل مثل الفشل الجراحي، والمضاعفات، وعدم امتثال المريض. وقد تم تطبيق نموذج سكاني لتتبع تأثير الجراحة على الأفراد الذين أجريت لهم العملية. وترتكز تقديرات التكاليف على المعطيات الأولية التي جمعتها فرق إقليمية لتقدير التكلفة من ١٤ إقليماً وبائياً فرعياً، وعلى مراجعة للدراسات ذات الصلة. وتم تقدير تكاليف مستويات مختلفة للتغطية الجغرافية باستخدام الدالات غير الخطية للتكلفة.

الموجودات: تعتبر جراحات الساد (الكاتاراكت) داخل أو خارج المحفظة طرقاً فعالة في خفض حالات العمى الناجم عن الساد (الكاتاراكت). وتزداد مردودية جراحة الساد (الكاتاراكت) خارج المحفظة بالمقارنة مع الجراحة داخل المحفظة في جميع المناطق المدروسة. ومن شأن إجراء جراحة الساد (الكاتاراكت) خارج المحفظة لنسبة ٩٥٪ من المحتاجين إليها (أي بمستوى تغطية ٩٥٪) أن توفر أكثر من ٣,٥ ملايين من سنوات العمر المصححة باحتساب مدد العجز على المستوى العالمي في كل عام. وتتراوح المردودية من ٥٧ دولاراً دولياً لكل سنة من سنوات العمر المصححة باحتساب مدد العجز، وذلك في إقليم جنوب شرق آسيا الذي يعاني من ارتفاع وفيات الأطفال والبالغين، إلى ٢٣٠٧ دولارات لكل سنة من سنوات العمر في إقليم غرب الهادي الذي يتميز بانخفاض وفيات الأطفال والبالغين.

الحصيلة: تُعتبر جراحة الساد (الكاتاراكت) خارج المحفظة بمستوى تغطية مرتفع هي الطريقة الأكثر مردودية لإعادة البصر في جميع الأقاليم الوبائية الفرعية المدروسة. ويُوصَى المحللون في بلدان كل إقليم بإجراء مزيد من المواءمة للنتائج وفقاً للمتثابتات النوعية لبلدانهم.

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Box 1. **WHO-CHOICE**

WHO seeks to provide the evidence decision-makers need to set priorities and improve the performance of their health systems. The Global Programme on Evidence for Health Policy (GPE) is assembling regional databases on the costs, impact on population health and cost effectiveness of key health interventions. This work is known as WHO-CHOICE. It started in 1998 with the development of standardized tools and methods. The objectives of WHO-CHOICE are to:

- Develop a standardized method for cost-effectiveness analysis that can be applied to all interventions in different settings
- Develop and disseminate tools required to assess intervention costs and impacts at the population level
- Determine the costs and effectiveness of a wide range of health interventions when presented with probabilistic uncertainty analysis
- Summarize the results in regional databases that will be available on the Internet
- Assist policy-makers and other stakeholders to interpret and use the evidence.

Box 3. **International dollars**

Results are presented in International dollars for the year 2000. An International dollar has the same purchasing power that the United States dollar has in the United States. Costs in local currency units are converted to International dollars using purchasing power parity (PPP) exchange rates. A PPP exchange rate is the number of units of a country's currency required to buy the same amounts of goods and services in the domestic market as a US dollar would buy in the United States. An International dollar is a hypothetical currency that is used as a means of translating and comparing costs from one country to the other using a common reference point. The PPP exchange rates used in this analysis were developed by WHO and are available on the WHO-CHOICE web site. More background information on International dollars and PPP can be found in reference *8*.

Table 4. **Example of results of uncertainty analysis in cost per DALY averted for African region at mortality stratum D**

	Type of surgery and population coverage	Mean cost[a]	Percentile interval	
			5%	95%
A	ICCE–AG (50%)	I$ 190	I$ 141	I$ 247
B	ICCE–AG (80%)	I$ 161	I$ 101	I$ 225
C	ICCE–AG (95%)	I$ 158	I$ 53	I$ 213
D	ECCE–PC–IOL (50%)	I$ 107	I$ 48	I$ 188
E	ECCE–PC–IOL (80%)	I$ 91	I$ 42	I$ 155
F	ECCE–PC–IOL (95%)	I$ 89	I$ 39	I$ 148

[a] Costs calculated in International dollars (I$).