



REVIEW

# Economic Evaluation of Cataract: A Systematic Mapping Review

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## ABSTRACT

**Introduction:** The purpose of this article was to ascertain the existing literature and find the gaps in economic evaluations of cataracts.

**Methods:** Systematic methods were used to search and collect the published literature on economic evaluations of cataracts. A mapping review of studies published in the following bibliographical databases was performed: the National Library of Medicine (PubMed), EMBASE, Web of Science (WOS), and the Central of Reviews and Dissemination (CRD) database. A

descriptive analysis was conducted and relevant studies were classified into different groups.

**Results:** Among 984 studies screened, 56 studies were included in the mapping review. Four research questions were answered. There has been a progressive increase of publications during the last decade. The majority of the included studies were published by authors from institutions in the USA and UK. The most commonly investigated area was cataract surgery followed by intraocular lenses (IOLs). The studies were classified into different categories according to the main outcome evaluated, such as comparisons between different surgical techniques, costs of the cataract surgery, second eye cataract surgery costs, quality of life gain after cataract surgery, waiting time of cataract surgery and costs, and cataract evaluation, follow-

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up, and costs. In the IOL classification, the most frequently studied area was the comparison between monofocal and multifocal IOLs, followed by the comparison between toric and monofocal IOLs.

**Conclusions:** Cataract surgery is a cost-effective procedure compared with other non-ophthalmic and ophthalmic interventions and surgery waiting time is an important factor to consider because vision loss has a huge and broad-ranging impact on society. Numerous gaps and inconsistencies are found among the studies included. For this reason, there is a need for further studies according to the classification described in the mapping review.

**Keywords:** Cataract; Cost-effectiveness analysis; And cost–utility analysis

### Key Summary Points

Costs of healthcare are increasing, and therefore the importance of quality and efficiency is higher. Economic evaluations are used as a source of information by economists and healthcare providers to make the best decisions.

In the ophthalmology field, the economic evaluation of healthcare has become an important area to explore. Several studies have analyzed the economic impact of vision impairment due to cataracts; however, there are still different areas to investigate and gaps to find in the published literature.

A systematic mapping review was conducted to identify gaps in the literature and to analyze and categorize the existing evidence of economic evaluations in the ophthalmic area of cataracts that can be helpful for guiding future research.

The results provide evidence that cataract surgery is a cost-effective procedure compared with other non-ophthalmic and ophthalmic interventions and surgery waiting time is an important factor to consider because vision loss has a huge and broad-ranging impact on society.

## INTRODUCTION

Cataract is the leading cause of blindness and the second most common cause of vision impairment in adults [1]. In 2020, approximately 596 million people had distance vision impairment worldwide, of whom 43 million were blind and 83.48 million had moderate or severe vision impairment (MSVI) [1, 2]. Vision impairment and eye health can impact general health and well-being, thereby reducing quality of life [3]. In spite of the high rate of MSVI, more than 90% have a preventable treatable cause, such as cataracts, with existing highly cost-effective interventions [1].

Currently, the costs of healthcare are increasing, and therefore the importance of quality and efficiency is higher. In the ophthalmology field, the economic evaluation of healthcare has become an important area to explore, which is getting more common as healthcare is becoming more expensive [4]. Nevertheless, in these times, how much is one willing to invest in terms of vision health in society? Several studies have analyzed the economic impact of vision impairment due to cataracts and have summarized what is actually known [1, 4–7], even though there are still different areas to investigate and gaps to find in the published literature.

There are different types of economic evaluation in healthcare: cost–consequence analysis (CCA), cost-minimization analysis (CMA), cost-effectiveness analysis (CEA), cost–utility analysis (CUA), and cost–benefit analysis (CBA) [8]. Studies of CEA measure the effects of health outcomes in physical units, such as visual acuity (VA), and patient-reported outcomes (PRO); however, one cannot compare costs and different health interventions which are not in the same units [9]. Comparisons of costs and different health interventions are possible owing to CUA [10]. In contrast to cost-effectiveness studies, which use measurable outcomes, CUA use the dimensionless utility as the outcome parameter. The utility value has been quantified by decision theory methods and psychometric survey methods [7]. One of the most commonly used decision theory methods is the time trade-

off (TTO), by which participants have to specify the survival probability they will tolerate to eliminate the medical condition [11]. The higher the number of life years treated (TTO) or the greater the willingness to take risk, the lower the health-related quality of life (HRQoL) associated with the medical condition. HRQoL has been considered a utility variable, with many ways existing to measure it, the most widely used among others being the 5-dimension EuroQol (EQ5D), Health Utilities Index Mark (HUI3), and the 36-item Short Form Survey (SF-36) [12].

The CUA is a type of CEA in which health effects are measured in terms of quality-adjusted life years (QALYs) [13] or disability-adjusted life years (DALYs) in an attempt to capture the two most important features of a health intervention: the effect on survival measured in terms of life years and the effect on quality of life [8]. Several alternatives have been proposed as a unit measure of the CUA; however, the most accepted and used is the QALY [14]. QALYs are calculated by weighting each time interval in a given state by its “utility” on a scale ranging from 0 (death) to 1 (perfect health or normal vision) [13, 15, 16]. The utility value of a patient is a reflection of their preferences, and describes how a patient is able to shape their daily living tasks and allows an objective measurement of quality of life associated with a health state [17]. The higher the utility value, the better quality of life associated with a health state; the lower the value, the poorer the quality of life [18]. Therefore, an improvement in utility value can be used as an objective measurement of efficacy of any medical process to improve a patient’s quality of life [17].

Considering the exponential increase of systematic reviews and meta-analyses in the last decade, there is a need to evaluate the existing evidence using systematic methods. Evidence mapping is one of these emerging methodologies to analyze, categorize, and identify gaps in the literature [19, 20]. For this reason the aim of this study was to map the existing evidence of economic evaluations in the ophthalmic area of cataracts that can be helpful for guiding future research. The article is based on previously conducted studies and does not contain any

new studies with human participants or animals performed by any of the authors.

## MATERIAL AND METHODS

A systematic mapping review was conducted, which is one of the 14 types of reviews in the family of systematic reviews [21]. This type of review has been developed to describe the state of knowledge for a given question within a particular topic and it describes results narratively to answer the question. The term “scoping review” is often used interchangeably with the term “mapping review” owing to their methodological similarities. However, they can be distinguished from scoping reviews, because the subsequent outcome may involve further review of primary research, which is not known previously [21].

### Sources of Information and Search Strategy

A comprehensive literature search was performed in June 2021 using the following bibliographical databases: the National Library of Medicine (PubMed), EMBASE, and Web of Science (WOS). Moreover, an additional search of publications was performed in a specialized database, the Centre for Reviews and Dissemination CRD’s NHS Economic Evaluations Database (NHS EED) [22, 23], which contains summaries of economic evaluations. The keywords used in the strategy search were cost-effectiveness analysis, cost–utility analysis, and cataracts. The search strategy included the “cost-effectiveness analysis” because some authors refer to healthcare economic analyses measured as cost/quality-adjusted life years (QALY) cost-effectiveness analyses, whereas those in countries other than the USA refer to them as cost–utility analyses [24]. The final search for each database is shown in Table 1. Additionally, the search with the descriptors used is summarized in the Supplementary Material. The final literature search was concluded on June 17, 2022.

## Inclusion Criteria of Studies

The study included full economic evaluations that had to be original articles conducting a CUA or CEA in the field of cataracts. The population of interest for this mapping review was all individuals with cataracts regardless of their age, sex, race, and socioeconomic status. However, studies with a population having disease additional to cataracts were excluded. No restrictions were applied with regard to study design, although systematic reviews, whose main objective is to summarize results of cost-effectiveness or cost-utility analyses, were excluded. Only systematic reviews of randomized control studies (RCT) and observational studies which conduct an economic evaluation of the summarized data were included. Additionally, studies about expert guidelines or opinions, and non-original articles were excluded.

**Table 1** Search strategy

| Database   | Search strategy  |
|------------|--|
| Pubmed     | (cataract*[Title/Abstract] OR cataract*[MeSH Terms]) AND (analysis,cost[mh:noexp] OR effectiveness,cost[mh:noexp] OR "cost utility"[Title/Abstract] OR "effectiveness analysis"[Title/Abstract] OR "cost effectiveness"[Title/Abstract] OR QALY[Title/Abstract]) |
| Embase     | ('cost benefit analysis'/de OR 'cost effectiveness analysis'/de OR 'cost effectiveness analysis' OR 'cost utility analysis'/de) AND 'cataract':ab,ti   |
| WOS        | ((((TI = ("cost benefit*")) OR AB = ("cost benefit*")) OR ((TI = ("cost utility*")) OR AB = ("cost utility*")) OR ((TI = ("cost effective*")) OR AB = ("cost effective*")))) AND ((TI = (CATARACT*)) OR AB = (CATARACT*)))                                       |
| CRD<br>NHS | (MeSH DESCRIPTOR Cost-Benefit Analysis EXPLODE ALL TREES) AND (CATARACT)   |

## Extraction and Analysis of Data

Two reviewers (JG and NB) independently screened titles and abstracts and then obtained full-text articles that could be considered as potentially relevant. Inclusion assessment was done by one reviewer (JG) and checked by the second reviewer (NB). Disagreements between reviewers were resolved by deliberation and consensus, which included an impartial third reviewer if needed.

A single reviewer was sufficient for the data extraction and the verification of data extraction of a random sample. However, a second reviewer performed all verification of data extraction of a random sample to minimize bias [25].

The definition of research questions (RQs) is a key methodological aspect for a successful systematic mapping review [26, 27]. For this systematic mapping review, four RQs were defined:

- RQ1 How many papers have been published on economic evaluations of cataracts? Is there any temporal trend? What is the geographical distribution of the review authors?
- RQ2 What were the most commonly investigated economic evaluation techniques?
- RQ3 Which areas are the focus of research in the economic evaluation of cataracts?
- RQ4 Which were the variables most commonly included in the economic evaluation?

## RESULTS

### Literature Search Results

The literature search identified 1632 citations, from which 648 were excluded as duplicates and 984 records were screened. Of these, 242 reports were selected for full-text review and assessed for eligibility. Finally, 56 studies were included in the mapping review (Fig. 1, PRISMA flow diagram) [28] (Supplementary Table 5). The four previously detailed research questions

are described in the following section based on the selected literature.

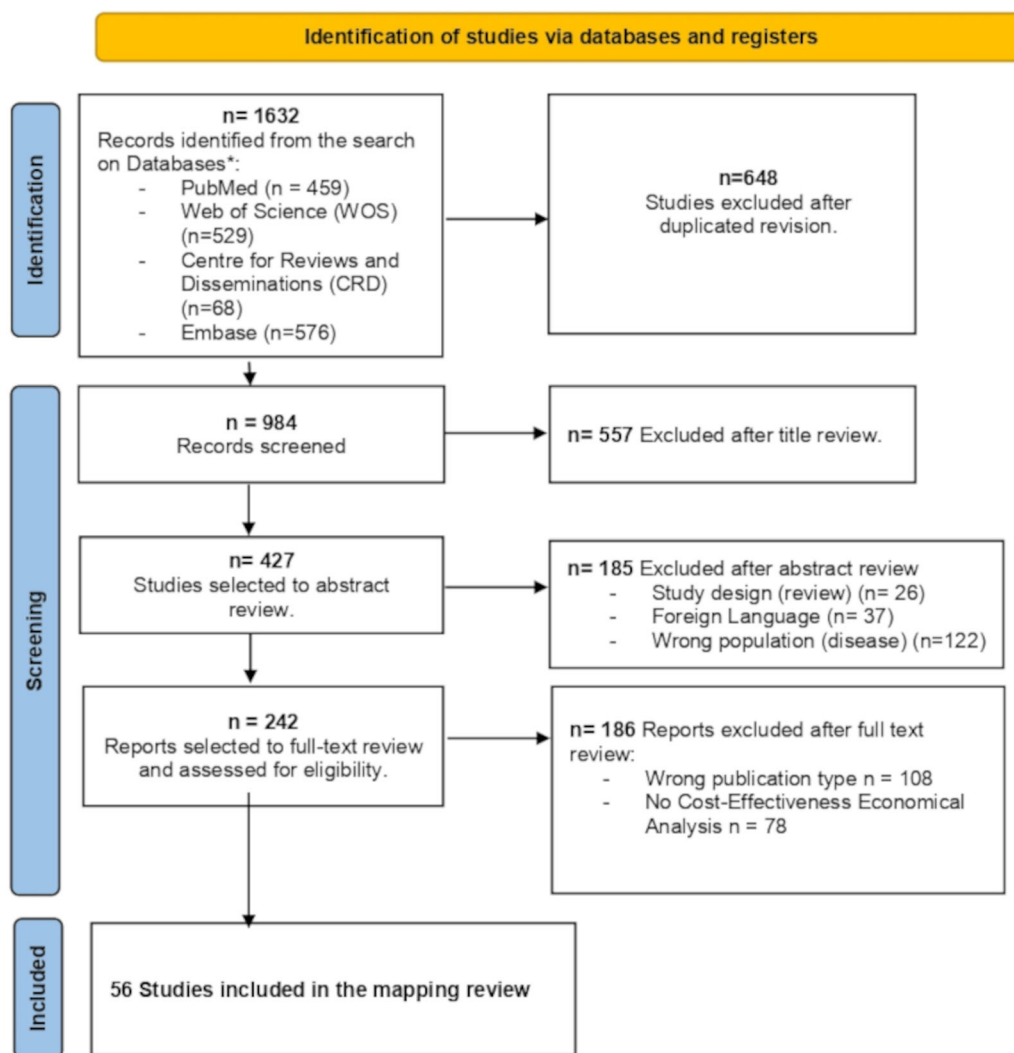
*RQ1.* How many papers have been published on economic evaluations of cataracts? Is there any temporal trend? What is the geographical distribution of the review authors?

As shown in Fig. 2, the earliest study included was published in 1988. No more economic evaluations of cataracts were included until 1996. However, there was not a progressive increase of published studies until 2002, growing from 4 studies published to 56 in 2022. The last 4 years have seen the greatest increase of studies published.

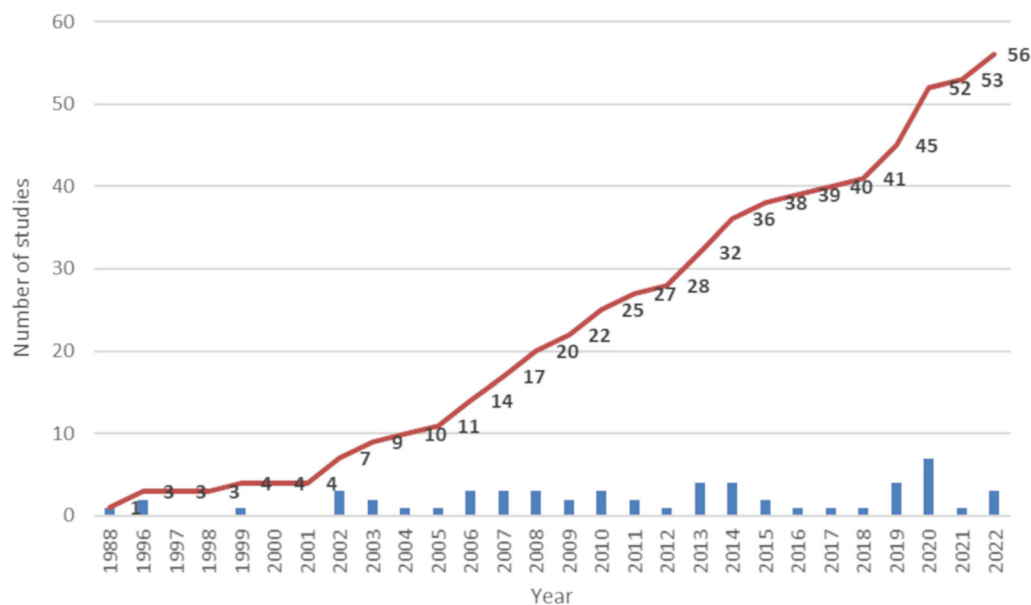
Economic studies were published by authors from many countries over the world; however, the majority were carried out by researchers from institutions in the USA ( $n = 7$ ), followed by the UK ( $n = 5$ ).

*RQ2.* What were the most commonly investigated economic evaluation techniques?

As shown in Supplementary Table 5, from 56 studies, 45 were described as a CEA, which compares the cost effects of cataract interventions and assesses the impact on specific clinical interventions, such as VA or PRO. An extension of the CEA is the CUA, by which the cost effects of cataract interventions are evaluated in terms



**Fig. 1** PRISMA flow diagram illustrating literature research and selection process



**Fig. 2** Cumulative publications per year in economic evaluations of cataracts. The red line represents the exponential adjustment of the number of publications

of quantity (life years) and quality of life (QALYs).

**RQ3.** Which areas are the focus of research in the economic evaluation of cataracts?

As a result of classifying publications according to the principal areas of research, the majority of the studies were classified as cataract surgery economic evaluations ( $n = 43$ ) (Tables 2, 3, 4, 5, 6, and 7) followed by intraocular lenses (IOL) ( $n = 13$ ) (Table 8). Among the economic evaluations applied to cataract surgery or IOLs, the studies were classified into categories according to the main outcome evaluated, such as surgical techniques (Table 2), cataract surgery costs (Table 3), second eye cataract surgery costs (Table 4), quality of life gain after cataract surgery (Table 5), waiting time of cataract surgery and costs (Table 6), and cataract evaluation, follow-up, and costs (Table 7). In the IOL classification, the most frequently studied area was the comparison between monofocal and multifocal IOLs, followed by the comparison between toric and monofocal IOLs (Table 8).

**RQ4.** Which were the variables most commonly included in the economic evaluation?

The most commonly included variables were QALY, DALY, and the incremental cost-effectiveness ratio (ICER). DALY has two components also included in some studies: years of life lost (YLL) and years lived with disability (YLD) [29–31]. The willingness to pay (WTP) is generally used in CBA; however, it has been included in some studies as a method of valuing health outcomes in monetary units [32]. In terms of HRQoL, as it has been already reported in the literature, the most widely used were EQ-5D and HUI3 [12]. In CUA, health effects are measured by QALYs [13] or DALYs [33]. Additionally, the ICER has been used to summarize the results of the economic evaluations of the health interventions [34].

## DISCUSSION

This is the first systematic mapping review carried out on the economic evaluation on cataracts, considering studies of CEA and CUA. The current mapping review includes relevant studies over a period of more than 30 years (1988–2022), providing a global overview of the current state of knowledge in the field of cataracts, health, and costs.

**Table 2** Comparison of surgical techniques versus costs

| Study                    | Main outcome     | Economic technique | Time horizon | Variables evaluated       | Discount rate |
|--------------------------|------------------|--------------------|--------------|---------------------------|---------------|
| Asimakis et al. [35]     | ECCE versus PCS  | CEA                | 1 year       | Costs/VA                  | –             |
| Rizal et al. [36]        | ECCE versus PCS  | CEA                | 20 years     | Elements of surgery costs | 5%            |
| Rizal et al. [37]        | ECCE versus PCS  | CEA                | 18 months    | VFQ-14/ICER               | 5%            |
| Jongsareejit et al. [38] | MSICS versus PCS | CEA                | 1 year       | ICER/VA                   | –             |
| Abell et al. [39]        | LCS versus PCS   | CEA and CUA        | 10 years     | VA/QALY/ICER              | –             |
| Khan et al. [40]         | PCS versus MSICS | CEA                | 1 year       | VA/VF-14/QALY             | –             |
| Schweitzer et al. [41]   | LCS versus PCS   | CEA                | –            | QALY/ICER/VA              | –             |
| Wulandari et al. [42]    | MSICS versus PCS | CEA                | –            | VF-25/QALY/ICER           | –             |
| Rochmah et al. [30]      | PCS versus SICS  | CEA                | –            | DALY/ICER/YLL/YLD         | –             |

*CEA* cost-effectiveness analysis, *CUA* cost–utility analysis, *ECCE* conventional extracapsular cataract extraction, *PCS* phacoemulsification, *MSICS* manual small incision cataract surgery, *SICS* small incision cataract surgery, *LCS* femtosecond laser assisted-cataract surgery, *VA* visual acuity, *ICER* incremental cost-effectiveness ratio, *QALY* quality-adjusted life year, *DALY* disability-adjusted life year, *YLL* years of life lost, *YLD* years lost due to disability

A total of 56 articles were selected from the initial 984 non-duplicated studies from four bibliographical databases (PubMed, WOS, CRD, Embase). As shown in Fig. 2, the number of papers published has increased in the last decade, most notably in the last 4 years. Therefore, a great increase in interest in research on economic evaluations of cataracts has occurred recently.

Comparison between surgical techniques in cataract surgery was one of the most commonly investigated areas. Conventional extracapsular surgery (ECCE), manual small incision cataract surgery (MSICS), and femtosecond laser-assisted cataract surgery (LCS) were compared versus phacoemulsification (PCS). Asimakis et al. [35] in 1996 evaluated the cost-effectiveness of cataract surgery comparing ECCE and PCS, and their results showed that ECCE generates slightly lower costs than PCS. Rizal et al. [36]

showed similar results, with ECCE being more cost-effective compared to PCS [37].

With the introduction of new techniques such as MSICS, Jongsareejit et al. [38] reported the similar effectiveness of MSICS and PCS, but PCS had higher costs. Therefore, MSICS had better cost-effectiveness than PCS. Khan et al. [40] also compared the cost-effectiveness of PCS versus MSICS, concluding that MSICS provided comparable visual and QALY improvement, taking less time, and consequently being more cost-effective than PCS. Opposite results were published by Wulandari et al. [42] and Rochman et al. [30], concluding that PCS was more cost-effective than MSICS.

Other authors compared the cost-effectiveness of LCS with conventional PCS. Abell et al. [39] showed that PCS was more cost-effective in spite of potential improvements in VA outcomes and complication rates. Schweitzer et al. [41] reported that despite its advanced

**Table 3** Cataract surgery versus costs

| Study                 | Main outcome   | Economic technique | Time horizon | Variables evaluated                          | Discount rate |
|-----------------------|--|--------------------|--------------|--|---------------|
| Tuominen et al. [43]  | Economic changes in cataract surgery   | CEA                | 10 years     | VA/surgery costs                             | 3%            |
| Marseille [44]        | Mortality rate of cataract surgery and costs   | CEA and CUA        | Lifetime     | DALY/surgery cost                            | 3%            |
| Busbee et al. [45]    | Cost–utility of initial cataract surgery   | CUA                | –            | CEAC/WTP/QALY                                | 3%            |
| Baltussen et al. [46] | Population health effects, costs, and cost-effectiveness of cataract surgery interventions | CEA                | –            | HYL/DALY                                     | 3%            |
| Räsänen et al. [47]   | Cataract surgery versus costs  | CUA                | Lifetime     | HRQoL/QALY/VA                                | 5%            |
| Lansingh et al. [48]  | Cataract surgery versus costs  | CEA and CUA        | 12 years     | CSAI/dollar/QALY/QALY/DALY/utility gain/ICER | 3%            |
| Sach et al. [49]      | Cost-effectiveness of first eye cataract surgery vs no surgery                             | CEA                | Lifetime     | EuroQoL EQ-5D/QALY/ICER/WTP/CEAC             | 3.5%          |
| Brown et al. [50]     | Cost–utility of cataract surgery   | CEA                | 13 years     | QALY/ROI/VA                                  | 3%            |
| Griffiths et al. [51] | Cost-effectiveness of cataract surgery and presbyopia                                      | CEA                | 5 years      | HRQoL/EQ-5D/VA/QALY/DALY                     | 3%            |
| Boyd et al. [52]      | Cataract surgery versus falls prevention   | CEA                | 1 year       | QALY/ICER/QALY gain/VA                       | –             |
| Essue et al. [53]     | Medical and non-medical cost associated with cataract                                      | CEA                | –            | CHE/DALY                                     | 3%            |
| Kapse et al. [31]     | Cost pediatric cataract surgery  | CEA                | 20 years     | DALY/YLL/YLD                                 | –             |

CEA cost-effectiveness analysis, CUA cost–utility analysis, VA visual acuity, ICER incremental cost-effectiveness ratio, QALY quality-adjusted life year, DALY disability-adjusted life year, YLL years of life lost, YLD years lost due to disability, CSAI Cataract Surgery Affordability Index, CEAC cost-effectiveness accessibility curve, ROI financial return on investment, HYL healthy years lived, WTP willingness to pay, CHE catastrophic health expenditure



**Table 4** Cataract surgery costs and second eye

| Study                | Main outcome  | Economic technique | Time horizon | Variables evaluated          | Discount rate |
|----------------------|---|--------------------|--------------|------------------------------|---------------|
| Busbee et al. [54]   | Case cost–utility analysis of second eye cataract surgery                       | CUA                | –            | VA/QALY/cost per QALY gained | 3%            |
| Sach et al. [55]     | Second eye cataract surgery costs versus patients already operated on first eye | CEA and CUA        | Lifetime     | QALY/EQ-D5/ICER/CEAC/WTP     | 3%            |
| Frampton et al. [56] | First eye versus second eye   | CEA                | Lifetime     | QALY/ICER/WTP                | 3.5%          |
| Cooper et al. [57]   | First eye versus second eye   | CEA                | 25 years     | QALY/ICER                    | 3.5%          |

CEA cost-effectiveness analysis, CUA cost–utility analysis, VA visual acuity, ICER incremental cost-effectiveness ratio, QALY quality-adjusted life year, WTP willingness to pay

technology, LCS was not cost-effective compared with PCS. LCS had higher costs and did not provide an additional benefit over PCS for patients or health systems.

Removal of cataracts may be among the most cost-effective of all ophthalmological interventions, as the surgical procedure can be carried out in less than 5 min, being almost always successful, and providing increase in utility after surgery. Therefore, in low-income countries, cataract surgery programs should be given high priority consideration in the planning health services [44]. Although there are no standardized definitions for what is considered cost-effective, it has been suggested that interventions costing less than \$20,000/QALY gain are highly cost-effective, whereas those costing more than \$100,000/QALY are not cost-effective [45, 87].

Throughout the course of cataract surgery, different countries have evaluated its cost-effectiveness compared with other surgical interventions. It has been proved that cataract surgery is more cost-effective than other ophthalmic and non-ophthalmic health interventions comparing cost/QALY gain of each intervention [44–46], being considerably cheaper in Europe and Canada compared with the USA [48].

Nevertheless, Räsänen et al. [47] obtained low results of the mean utility gain after cataract surgery. The majority of patients included in their study only reported minimal seeing problems in the surgical eye, which might have reduced the benefit of cataract surgery, and consequently would explain the small increase in HRQoL after the intervention. The cost–utility of cataract surgery varies substantially depending how the benefit is assessed and the duration of the assumed benefit. Results of CUA in the USA demonstrated that cataract surgery greatly improved quality of life and was highly cost-effective, decreasing its cost over the time, being 34.4% less expensive in 2012 than in 2000, and 85% less expensive than in 1985 [50].

Cataract surgery resulted in a cost-effectiveness intervention of restoring sight in different parts of the world, e.g., Zambia [46], Vietnam [53], New Zealand [66], or Japan [63]. According to accepted international benchmarks, cataract surgery and presbyopia correction can be considered highly cost-effective in Zambia. However, severe health system and human resource constraints make it difficult to scale up services [51]. Expedited cataract surgery appears very cost-effective in New Zealand, being considered itself very cost-effective, and its value appears largely driven by the falls prevention benefits [66]. According to the literature, cataract

**Table 5** Quality of life gain after cataract surgery

| Study                | Main outcome   | Economic technique | Time horizon | Variables evaluated  | Discount rate |
|----------------------|--|--------------------|--------------|--|---------------|
| Kobelt et al. [58]   | Cost QALY gained with cataract surgery                                       | CEA                | 2 months     | Catquest/EQ-5D/VA/<br>EuroQol questionnaires/<br>QALY/DALY | 3%            |
| Naeim et al. [59]    | Cataract surgery and probability of improvement in visual function           | CUA and CEA        | Lifetime     | VA/ADVS/HUI3/SF-12/cost/<br>QALY/QALY gain                 | 3%            |
| Lansingh et al. [60] | Cost–utility of cataract surgery using VA                                    | CUA and CEA        | Lifetime     | QALY/VA  | 3%            |
| Hiratsuka [61]       | Cost-effectiveness of cataract surgery through QALY                          | CEA                | –            | EQ5D/HUI3/QALY/VA  | 3%            |
| Weale [62]           | Quality of life gain after cataract surgery                                  | CB                 | –            | QALY/VA/EQD5   | 3.5%          |
| Hiratsuka [63]       | Cost-effectiveness of cataract surgery through QALYs                         | CEA                | 20 years     | QALY/ICER/WTP  | 3%            |
| Moore et al. [64]    | Visual results after cataract surgery  | CUA and CEA        | Lifetime     | QALY/QALY gain/<br>cost–utility ratio                      | 3%            |
| Brown et al. [65]    | Cost–utility of cataract surgery and quality of life                         | CUA                | 14 years     | QALY/VA  | 3%            |
| Boyd et al. [66]     | Health gain, health system costs, and cost-effectiveness of cataract surgery | CEA                | 20 years     | QALY/ICER  | 3%            |

CEA cost-effectiveness analysis, CUA cost–utility analysis, CB cost–benefit, VA visual acuity, ICER incremental cost-effectiveness ratio, QALY quality-adjusted life year, WTP willingness to pay, DALY disability-adjusted life year, EQ-D5 Euro Quality of Life, ADVS Activities of Daily Vision Scale, HUI3 Health Utility Index Mark 3, SF-12 12-Item Short Form Survey 12

surgery has been demonstrated to be good value in terms of benefits net of costs, except for patients whose vision is good at the time of their operation [62].

Concerning cataract surgery waiting times, developed economies like Australia [29] and Canada [67] have evaluated the importance of reducing waiting times for cataract surgery, reporting gains in broad patient outcomes, such as quality of life. These gains can be achieved with good value for money [29, 67].

First eye cataract surgery has been associated with gain in visual function, visual disability, activity, anxiety and depression, confidence and quality of life, resulting cost-effective, especially if a lifelong time frame is considered [49]. On the other hand, second eye cataract surgery has been reported as an extremely cost-effective procedure in ophthalmology when compared with other interventions across medical specialties. Busbee et al. [54] investigated the benefit gained from second eye

**Table 6** Waiting time for cataract surgery and costs

| Study                       | Main outcome                  | Economic technique | Time horizon | Variables evaluated                        | Discount rate |
|-----------------------------|-------------------------------|--------------------|--------------|--|---------------|
| Hopkins et al. [67]         | Waiting time cataract surgery | CEA                | 10 years     | ICER/QALY                                  | –             |
| Lundström [68]              | ISCS vs DSCS                  | CEA                | Lifetime     | Catquest/VA/surgery costs/capability Index | –             |
| Malvankar-Mehta et al. [69] | ISCS vs DSCS                  | CEA and CUA        | –            | QALY/ICER/VA                               | 3%            |
| Cernat et al. [70]          | ISCS versus DSCS              | CEA                | 8 weeks      | Costs/ICER                                 | 0%            |

CEA cost-effectiveness analysis, CUA cost–utility analysis, ISCS immediate sequential cataract surgery, DSCS delayed sequential cataract surgery, VA visual acuity, ICER incremental cost-effectiveness ratio, QALY quality-adjusted life year

cataract surgery, and showed in their results slight differences in cost/QALY gained from first eye surgery, suggesting that patients with good vision in one eye and visual loss from cataract in the fellow eye derive substantial benefit from cataract extraction.

Above all, cataract surgery in the first eye, second eye, or both eyes conferred considerable patient value and was very cost-effective by any standard. Both patient value gain and cost-effectiveness have improved since 2012 and before. Cataract surgery in 2018 was 75% more cost-effective than in 2000 in the USA [65]. In bilateral cataract patients, the replacement of the lens in the worst-affected eye was considered as a cost-effective way to improve vision and quality of life. However, it was unclear whether or not lens replacement surgery in the second eye provided enough further benefit to be considered worthwhile by patients and cost-effective for a health system. Health systems, such as the National Health System (NHS) in the UK, have investigated the benefit of the second eye cataract surgery [56, 57]. Results from the NHS showed that second eye cataract surgery is generally cost-effective in the long term, being unlikely cost-effective in the short term for those with mild visual dysfunction pre-operatively [56, 57].

The TTO method is used to determine utility values. At the same time, it is accepted as a formal method for quantifying the relative impact of a given health state or disease on

patient lives [7, 16, 61]. VA and visual disability significantly affect utilities controlled for age and ophthalmic comorbidity. It is thus possible to use data on VA and disability in large registries to estimate the cost-effectiveness of cataract surgery and to compare the cost per QALY gained with other healthcare interventions [58]. Several studies reported that cataract surgery is cost-effective, improves patient perceived quality of life, even in a subpopulation of patient with a lower predicted probability of reporting improved visual functioning after surgery [59–61, 63].

In general, bilateral cataract extraction can be performed with varying interval between the two surgeries: immediate sequential cataract surgery (ISCS) or delayed sequential cataract surgery (DSCS), with an interval of weeks or months between surgeries. Several studies have reported that ISCS is a cost-effective procedure compared with DSCS. The value for the patient of ISCS compared to DSCS depends on how long the period will be between first and second eye surgery in DSCS and also on the patient's survival time after surgery [68, 69].

Currently, the high prevalence of cataract is still a public health problem. CEA are evaluated for surgical techniques; however, costs of clinical systems of cataract grading and preoperative new measurements have also been investigated. The high costs of setting up the novel technology are offset by low running costs [71, 72]. In fact, other preoperative screening

**Table 7** Cataract evaluation, follow-up, and costs

| Study                   | Main outcome   | Economic technique | Time horizon | Variables evaluated           | Discount rate |
|-------------------------|--|--------------------|--------------|-------------------------------|---------------|
| Dimock et al. [71]      | Cataract grading system versus human cataract photograph                               | CEA                | 5 years      | ICER                          | –             |
| Taylor et al. [29]      | Vision loss and costs  | CEA                | Lifetime     | YLD/YLL/<br>DALY/VLY          | 3.3%          |
| Jastrzebski et al. [72] | Safety and costs of traditional mandatory Preoperative assessment for cataract surgery | CEA                | –            | Surgery costs,<br>PRO         | –             |
| Meltzer et al. [73]     | Follow-up after cataract surgery creates economic value                                | CEA                | –            | VA/WTP/<br>ICER/surgery costs | –             |
| Leung et al. [74]       | Screening with OCT versus without  | CEA                | 15 years     | ICER/ICUR/<br>QALY/VA         | 3%            |

*CEA* cost-effectiveness analysis, *CUA* cost–utility analysis, *OCT* optical coherence tomography, *VA* visual acuity, *ICER* incremental cost-effectiveness ratio, *ICUR* incremental cost–utility ratio, *QALY* quality-adjusted life year, *DALY* disability-adjusted life year, *YLL* years of life lost, *YLD* years lost due to disability, *VLY* value for a statistical life year, *PRO* patient-reported outcomes, *WTP* willingness to pay

measurements have been evaluated, such as optical coherence tomography (OCT) during the evaluation of a patient considering cataract surgery, being cost-effective from a third-party payer and societal perspective, as it could increase the detection of macular pathologies and improved the QALYs over time [74].

Numerous studies have estimated the cost-effectiveness of cataract surgery with multifocal IOLs compared to monofocal IOLs [75–79]. Orme et al. [75] showed that multifocal IOLs are cost-effective for patients who desire spectacle independence. However, multifocal IOLs may not be the most cost-effective options for patients who require excellent night vision or do not tolerate any visual disturbances, such as glare or halos. Similar results were described by Hu et al. [79] and Bala et al. [86], considering multifocal diffractive IOL and non-diffractive EDOF IOLs as cost-effective strategies compared to monofocal IOLs for patients seeking spectacle independence.

Lafuma et al. [76] and De Vries et al. [77] compared lifetime costs of spectacle independence after cataract surgery, concluding that multifocal IOLs are a cost-saving alternative to spectacles for patients requiring cataract

surgery. Maxwell et al. [32] also proved that the net benefit of the multifocal IOL exceeded its acquisition cost and the net benefit of the monofocal IOL, demonstrating its value to select patients with cataract willing to pay a premium for spectacle independence. Lin et al. [78] showed that multifocal IOLs provide better effectiveness on vision-related indicators like postoperative ICER of postoperative spectacle independence rate and binocular best-corrected VA in near vision.

Other authors have evaluated the cost-effectiveness of toric IOLs in patients with corneal astigmatism compared with monofocal IOLs [81, 83]. Pineda et al. [81] evaluated the economic value of improved uncorrected distance VA after surgery. Their results showed that toric IOLs had higher total costs during the first year, but were lower across patients' lifetimes. Treating astigmatism with toric IOLs at the time of cataract removal yielded several important benefits, such as VA and patient HRQoL improvement, and consequently long-term healthcare cost-savings. However, opposite results were reported by Simons et al. [83] who concluded that toric IOLs were not cost-effective and increased healthcare costs in the short

**Table 8** Intraocular lenses studies and costs

| Study                     | Main outcome   | Economic technique | Time horizon | Variables evaluated                                   | Discount rate |
|---------------------------|--|--------------------|--------------|---|---------------|
| Orme. et al. [75]         | AMOArray multifocal IOL versus the foldable monofocal                                  | CEA                | –            | ICER/VA   | –             |
| Lafuma et al. [76]        | The multifocal IOL ReSTOR® versus monofocal IOLs                                       | CEA                | Lifetime     | PRO/costs   | 3%            |
| Maxwell et al. [32]       | Apodized, diffractive, presbyopia-correcting multifocal IOL compared to a conventional | CEA                | –            | WTP   | 3%            |
| De Vries et al. [77]      | Bilateral monofocal (SI40NB) or multifocal (ReSTOR or Array-SA40) IOL                  | CEA                | –            | ICER/VA   | 4%            |
| Lin et al. [78]           | Monofocal versus multifocal IOL  | CEA                | –            | VA, NEI VFQ-25, and spectacle-independence rates/ICER | –             |
| Hu et al. [79]            | Multifocal IOL versus monofocal IOLs   | CEA                | –            | QALY/ICER/WTP/halos/glare                             | 3%            |
| Smith et al. [80]         | IOL material PMMA and silicone   | CEA                | 3 years      | ICER  | 0%            |
| Pineda et al. [81]        | VA among patients with cataract and preexisting astigmatism treated with toric IOLs    | CEA                | Lifetime     | QALY/VA   | 3%            |
| Kristianslund et al. [82] | CEA to economically evaluate IOL repositioning versus IOL exchange                     | CEA                | 6 months     | VA/VF-14/QALY   | 3.5%          |
| Simons et al. [83]        | Toric versus monofocal IOL   | CEA                | Lifetime     | ICER/QALY/HRQL/HUI3/VA/WTP                            | 4%            |
| Jain et al. [84]          | Cataract surgery methods, IOLs, and quality of life                                    | CUA                | –            | EQ5D-5L/ IND-VFQ-33/QALY/VA                           | –             |
| Ranno et al. [85]         | Economical outcomes of patients with AC-IOL implantation and SF-IOL implantation       | CEA                | 2 years      | VA/ECD/VF-14/ICER                                     | –             |
| Bala et al. [86]          | AcrySof IQ Vivity EDOF versus monofocal aspheric IOL                                   | CEA                | 30 years     | VA/QALY/QALY ratio                                    | 5%            |

*CEA* cost-effectiveness analysis, *CUA* cost–utility analysis, *IOL* intraocular lens, *AC-IOL* secondary anterior chamber intraocular lens, *SF-IOL* secondary scleral fixated intraocular lens, *EDOF* extended depth of focus, *VA* visual acuity, *ICER* incremental cost-effectiveness ratio, *QALY* quality-adjusted life year, *PRO* patient-reported outcomes, *WTP* willingness to pay, *IND VFQ 33* 33-item Indian Vision Function Questionnaire, *NEI-VFQ-25* National Eye Institute 25-item Visual Function Questionnaire, *ECD* endothelial cell density

term. They found that although toric IOLs improved uncorrected distance visual acuity (UDVA) and spectacle independence after cataract surgery, there was not improvement in HRQoL. Discrepancies between studies could be due to the method used to determine QALYs by Pineda et al. [81] leading in an overestimation of toric IOL effectiveness.

Cost-effectiveness of different IOL materials implanted in cataract surgery has also been evaluated. Jain et al. [84] assessed the effects of different types of cataract surgeries and IOL materials as well as QALYs and vision-related quality of life of patients with cataract, using EQ-5D and IND-VFQ 33 instruments, respectively. All three types of surgical procedures (ECCE, PCS, and SICS) showed a QALY gain and vision-related quality of life gain. Rigid poly(methyl methacrylate) (PMMA) and foldable lenses were also analyzed in this study. Quality of life was found to be better in foldable lenses compared to the rigid lenses, and the authors recommended to use a foldable lens with PCS as the incision size is smaller and a rigid lens with ECCE and SICS because of the larger incision size. Results from Lafuma et al. [80] showed that cost-effectiveness ratios of hydrophobic acrylic IOLs were better than those of other types of IOL materials used in most countries. The study showed that at 3 years postoperatively, patients implanted with hydrophobic acrylic IOLs presented less often for Nd:YAG laser therapy than patients implanted with other materials such as PMMA, silicone, and hydrophilic acrylic.

In complicated cataract surgery, the absence of adequate capsular support necessitates alternative approaches to IOL placement, which include scleral fixation in the posterior chamber (SF-IOL), iris fixation, or placement in the anterior chamber angle (AC-IOL) in a single procedure or a subsequent surgery. Ranno et al. [85] compared visual, anatomical, and economic outcomes of patients with secondary AC-IOL implantation and secondary SF-IOL implantation. The global cost of implantation was significantly lower for AC-IOL, but the ICER justified the SF-IOL implantation in patients with low endothelial cell density (ECD). In their results, the authors showed that the ICER favored the secondary AC-IOL implantation in

elder patients with good ECD. Although PC-IOL had higher costs, it was recommended to be implanted in patients with low ECD and long life expectancy.

## STRENGTHS AND LIMITATIONS OF THE MAPPING REVIEW

The present systematic mapping review has some limitations. As an intrinsic characteristic of a mapping review, this study does not include extraction of study results or synthesis of results for a deep analysis [21]. Only English language publications were included, which could limit the inclusion of studies.

On the other hand, the limitations of this mapping review are coincident with other mapping reviews, such as no formal quality assessment or assessment applicability or usefulness of identified research methods [88]. Thus, the level of evidence was not evaluated for each study in order to provide information about quality of evidence of the studies included in the mapping review.

## FUTURE RESEARCH

Even though several studies have evaluated the cost-effectiveness between surgical techniques in cataract surgery, there are inconsistencies in their results. ECCE and MSICS seem to be cost-effective compared to PCS, and PCS is cost-effective compared with LCS. Given the differences between studies, there is a need for further investigations about cost-effectiveness and surgical methods in cataract surgery.

There was clear evidence that cataract surgery is more cost-effective than other ophthalmic and non-ophthalmic health interventions, improving visual function and patient perception quality of life. Cataract surgery costs have decreased over the years; however, their cost-effectiveness should be cautiously evaluated according to the country and the population assessed.

Cataract surgery waiting time is an important factor to consider as vision loss has a huge and broad-ranging impact on society. Priority

needs to be given to avoid preventable vision loss, to treat treatable eye diseases, and to increase research into vision loss from eye diseases that can be treated. ISCS has been demonstrated to be a more cost-effective method compared with DSCS. This finding could be highly useful for policy-makers, decision-makers, clinicians, hospital administrators, and payers in making cost-efficient decisions, although more robust studies are needed to confirm these findings.

First eye and especially second eye cataract surgery are the most cost-effective procedures in ophthalmology and other medical specialties. They are associated with gain visual function, visual disability, and quality of life among others. In spite of the large number of publications, there is a need for more research because of inconsistent results reported for short- and long-term outcomes of second eye cataract surgery.

Regarding to the peer-reviewed literature, new grading preoperative cataract systems and preoperative additional measurements such as OCT should be introduced in clinical practice to save time, costs, and resources by eliminating unnecessary patient visits. However, few studies have focused on the economic analysis of the preoperative protocols.

The desire for spectacle independence allowed by multifocal IOLs is greatly valued by patients with cataracts who are willing to pay for the advanced technology. Multifocal IOLs can be highly cost-effective for patients who prefer to be spectacle independent, and therefore it is important to ensure that patients have realistic expectations when making choices between monofocal and multifocal IOLs.

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