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Cost-Utility Analyses of Cataract Surgery in Advanced Age-Related Macular Degeneration

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ABSTRACT

Purpose. To explore the cost-utility of cataract surgery in patients with advanced age-related macular degeneration (AMD).

Methods. Patients who were diagnosed as having and treated for age-related cataract and with a history of advanced AMD at the Department of Ophthalmology, Shanghai General Hospital, Shanghai Jiao Tong University, were included in the study. All of the participants underwent successful phacoemulsification with foldable posterior chamber intraocular lens implantation under retrobulbar anesthesia. Best-corrected visual acuity (BCVA) and utility value elicited by time trade-off method from patients at 3-month postoperative time were compared with those before surgery. Quality-adjusted life years (QALYs) gained in a lifetime were calculated at a 3% annual discounted rate. Costs per QALY gained were calculated using the bootstrap method, and probabilities of being cost-effective were presented using a cost-effectiveness acceptability curve. Sensitivity analyses were performed to test the robustness of the results.

Results. Mean logarithm of the minimum angle of resolution BCVA in the operated eye increased from 1.37 ± 0.5 (Snellen, 20/469) to 0.98 ± 0.25 (Snellen, 20/191) ($p < 0.001$); BCVA in the weighted average from both eyes (=75% better eye + 25% worse eye) was changed from 1.13 ± 0.22 (Snellen, 20/270) to 0.96 ± 0.17 (Snellen, 20/182) ($p < 0.001$). Utility values from both patients and doctors increased significantly after surgery ($p < 0.001$ and $p = 0.007$). Patients gained 1.17 QALYs by cataract surgery in their lifetime. The cost per QALY was 8835 Chinese yuan (CNY) (1400 U.S. dollars [USD]). It is cost-effective at the threshold of 115,062 CNY (18,235 USD) per QALY in China recommended by the World Health Organization. The cost per QALY varied from 7045 CNY (1116 USD) to 94,178 CNY (14,925 USD) in sensitivity analyses.

Conclusions. Visual acuity and quality of life assessed by utility value improved significantly after surgery. Cataract surgery was a cost-effective intervention for patients with coexistent AMD.

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Key Words: advanced age-related macular degeneration, cataract surgery, cost-utility analysis, quality-adjusted life years, time trade-off

Age-related cataract and age-related macular degeneration (AMD) share the same risk factor of age and therefore often occur concurrently in people older than 50 years.¹ Advanced AMD, including dry AMD (geographic atrophy) and wet AMD (choroidal neovascularization), could lead to irreversible damage to central vision, metamorphopsia, scotoma, and, as a result, loss of vision-related quality of life (QOL).² With

advancement in surgical techniques during the past decades, cataract surgery could effectively improve visual acuity and QOL in patients without severe ocular comorbidities. However, for patients with coexistent advanced AMD, whether cataract surgery is beneficial has been controversial for a long time because the improvement of visual acuity is limited and because of the potential risk of progression in AMD.^{3–5} Most recently, the Age-Related Eye Diseases Study 2 (AREDS 2) reported an improvement of 6.8 letters ($p < 0.0001$) in patients with advanced AMD (central geographic atrophy and neovascular disease) after cataract surgery without progression of AMD.⁶ Studies that focus on outcomes of cataract surgery in patients with neovascular AMD under anti-vascular endothelial growth factor (VEGF) treatment also presented significant increases in visual acuity postoperatively without the increased need for injections.^{7,8} In addition, a Cochrane systematic review indicated that it still could not be confirmed from the present existing literature that cataract surgery results in the progression of AMD.⁹

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Currently, more and more researchers have realized that visual acuity alone is not adequate to assess the influence of ocular morbidities on patients. Other visual functions such as color vision, contrast sensitivity, night vision, visual field, and spatial vision could also be affected by ophthalmic diseases. An increasing number of researchers have incorporated QOL, measured by visual function questionnaires or utility values, in measuring the impact of diseases or major outcomes of therapeutic interventions. Utility values could evaluate QOL associated with various health states. Different from visual function questionnaires, utility values measure patients' subjective preferences rather than recording functional states. Specifically, two patients with the same reduction in near vision might experience different decreases in QOL, depending on the importance of near vision in their daily life. Therefore, utility values were regarded as qualified and comprehensive measures of QOL associated with certain health states. In addition, utility values allow comparisons of QOL between different diseases and medical specialties and facilitate further health economic evaluations.¹⁰

Cost-utility analysis combines the preference-based utility values and costs in evaluating the health economic value of therapeutic interventions.¹⁰ By measuring costs per quality-adjusted life year (QALY) conferred from interventions, it provides evidence for policy makers to decide specific priorities with which to allocate medical resources. For cataract surgery, it was regarded as a cost-effective therapeutic intervention for patients with initial cataract and second-eye cataract.^{11,12} Nevertheless, no literature has ever measured the cost-effectiveness of cataract surgery in patients with concurrent advanced AMD.

This study confirmed the improvement of visual acuity and utility values associated with cataract surgery in patients with both cataract and bilateral advanced AMD and measured costs per QALY gained in those patients. Correlations between utility values and scores from a vision-related QOL questionnaire were performed to demonstrate the validity of utility values from patients' aspect. This study attempted to explore the benefit of cataract surgery in patients with advanced AMD from the aspect of health economics.

METHODS

Participants, Data Collection, and Surgery

Patients who were diagnosed as having and treated for age-related cataract and with a history of advanced AMD at the Department of Ophthalmology, Shanghai General Hospital, Shanghai Jiao Tong University, between January 2006 and January 2012 were included in the study. Medical records from slitlamp biomicroscopy and fluorescent angiography examinations that confirmed the diagnosis of bilateral advanced AMD, including subfoveal geographic atrophy and subfoveal neovascularization, were required.¹³ In addition, the participants should have age-related cataract in at least one eye with nuclear hardness grade 3 or higher (nuclear hardness classification by Emery and Little¹⁴) and persevere in receiving cataract surgery, although they were fully explained the risks and the uncertain visual outcomes of the surgery. Patients who are not able to answer the questionnaires or follow-up during the study period were excluded from the study. The study adhered to the tenets of the Declaration of Helsinki and was approved by the institutional review board of the Shanghai General

Hospital, Shanghai Jiao Tong University. Written informed consent was obtained from all participants.

Name, sex, age, education level, systemic diseases, AMD duration, type of AMD, and so on were collected at baseline. All of the enrolled patients underwent successful phacoemulsification with foldable posterior chamber intraocular lens implantation through clear corneal incisions under retrobulbar anesthesia. The patients were followed for 3 months, and best-corrected visual acuity (BCVA) (measured at 5 m using a Snellen E chart), costs, QOL measured by a Chinese-version low-vision QOL (CLVQOL) questionnaire,¹⁵ and utility values were obtained before and 3 months after surgery. During the 3-month follow-up period, if a second-eye cataract surgery was performed, costs were also collected.

Costs, Utility Value, and Cost-Utility Analysis

All costs are expressed in Chinese yuan (CNY) and U.S. dollars (USD) using an exchange rate of USD 1 = 6.3 CYN (as of January 2012). The costs were calculated from a patient's perspective, and all of these costs were inflated to 2012 values by using the consumer price index in China.¹⁶ Self-designed investigation forms were distributed to obtain the costs associated with the cataract surgery, including the direct medical costs (examinations, pharmaceuticals, outpatient service fees, hospitalization, surgery, and treatment of surgical complications) and direct nonmedical costs (transportation fees). The costs obtained from this research were charged according to Chinese medical insurance unified prices.

The time trade-off method from both the patient's and doctor's perspective was used to elicit utility values. A skilled interviewer (HDZ), who was not involved in clinical observations, performed the time trade-off task. Each participant was asked how many additional years he or she expected to live and then how many of these theoretical remaining years, if any, he or she would be willing to trade in return for guaranteed permanently perfect vision in each eye. An ophthalmologist, who performed more than 10 years of cataract surgeries, was also asked to assume that he had the same vision-related QOL impairment as the patient under investigation, and the same questions were answered. The utility score was calculated by subtracting the quotient (years traded/years to live) from 1.0. For example, if a 50-year-old patient with a self-perceived life expectancy of 30 additional years preferred to trade 3 years to be rid of his or her visual functional impairment caused by the diseases, the utility score would be $(1.0 - 3/30) = 0.9$. The utility score can vary between 1.00 (perfect visual health) and 0.0 (death).

The benefit of cataract surgery could be lifelong. Therefore, we performed a long-term cost-utility analysis. We assumed that the utility values of the patients would remain constant for 3 months after surgery, and we calculated QALYs gained by the cataract surgery by multiplying the 3-month postoperative utility values by the patients' life expectancies.¹⁷ It was also assumed that hypothetical patients who were not treated would remain at their preoperative health status for their life expectancies and would not incur medical costs any longer. Quality-adjusted life years were discounted by 3% annually in the baseline analysis. Because all of the medical costs were paid during a 3-month period, they were not discounted. Dividing the cost by QALYs, the ratio represents cost per QALY gained by cataract surgery compared with no treatment in patients with bilateral advanced AMD.

Statistical Analysis

The BCVA fractions were all converted into logarithm of the minimum angle of resolution (logMAR) BCVA, and a logMAR BCVA of 2.2 was assigned for finger count. Weighted average BCVA was calculated by incorporating visual acuity of both eyes, with 75% weight from the better eye and 25% from the worse eye.¹⁸ A Kolmogorov-Smirnov test was used to test for normality before comparison. The Wilcoxon signed rank test was used to compare differences between preoperative and postoperative BCVA in the surgery eye, differences in utility values from the doctor's perspective before and after surgery, and differences in utility values from the patients and doctors. Paired sample t-tests were used in the comparison between the preoperative and postoperative weighted BCVA, CLVQOL scores, and utility values from the patient's perspective and comparison between changes in utility values from patients and doctors. Pearson correlation coefficients were calculated to explore the relationship between the utility values from the patients' aspect and QOL measured by CLVQOL scores because the latter was proven valid in evaluating vision-related QOL for various eye diseases in the Chinese population.^{15,19} Spearman correlation coefficients were calculated for utility values from the doctors' aspect and CLVQOL scores because the utility values from the doctors' aspect followed a non-normal distribution (preoperative utility values, $p = 0.003$; postoperative utility values, $p < 0.001$; Kolmogorov-Smirnov test). To detect a difference in visual acuity of 0.44 logMAR and a standard deviation (SD) of 0.48, as reported in previous literature,²⁰ a minimum sample size of 12 was required, with 80% power at a level of $\alpha = 0.05$. All of the tests were two-tailed, and a value of $p < 0.05$ was considered statistically significant.

Best-corrected visual acuity of the operative eye (here calculated as the average of both eyes if the patients underwent bilateral cataract surgery), weighted average BCVA, BCVA of the better eye, BCVA of the worse eye, age, sex, duration of AMD, education level (>12 years, $N = 1$; ≤ 12 years, $N = 0$), number of systemic diseases, and bilateral cataract surgery ($N = 0, 1$) were incorporated into multiple linear regression analyses to explore the associated factors of utility values. With an entry value of $p < 0.05$ and an exit value of $p = 0.10$, all of the independent variables were permitted in the model by the stepwise method. The above statistical analyses were performed by SPSS version 16.0.

Because data costs are usually skewed to the right and the uncertainty of cost per QALY is difficult to present using traditional statistical methods, nonparametric bootstrapping²¹ with 1000 replications was carried out on the incremental costs and QALYs using Microsoft Excel 2007 software to calculate the mean costs, mean QALYs gained, and costs per QALY. To reflect the uncertainty of costs and effects, a cost-effectiveness acceptability curve was drawn, representing the probability of cataract surgery being more cost-effective than no treatment for different thresholds of willingness to pay per QALY.²²

Sensitivity Analysis

Sensitivity analyses were conducted to test the robustness of the results. First, we examined the impact of floating the discount rate from the 3% assumed in the baseline scenario to 0 and 5%, as recommended.²³ Second, the costs were raised by 20 and 50%,

and the QALYs were decreased by 20 and 50%, respectively. Then, we increased the costs by 50% and reduced the QALYs by 50% simultaneously. In the baseline analysis, we assumed that the benefit of cataract surgery was lifelong. However, the improved visual function usually decreases with increasing follow-up time, especially for those with ocular comorbidities in the operated eye.²⁴ Hence, we performed additional 1- and 5-year analyses based on the assumption that the duration of the improved QOL will last for at least 1 year according to the AREDS studies and for 5 years according to models in other cost-utility analyses for cataract surgery.²⁵ Moreover, we included the costs for treating posterior capsular opacification assuming the highest incidence rate of 53% reported in the literature.²⁶ Finally, we made an additional analysis by incorporating disability weights from the Global Burden of Disease Study 2010²⁷ to calculate costs per disability-adjusted life year (DALY) averted, which corresponds to costs per QALY gained because cataract and AMD are not lethal. The visual impairment classification adhered to the World Health Organization recommendations.²⁸

RESULTS

Sixty-two patients were diagnosed as having advanced AMD and age-related cataract with nuclear hardness of grade 3 or higher and were willing to receive cataract surgery during the study period. Among them, six patients were unable to revisit after 3 months and 5 patients did not sign the written informed consent (Fig. 1). A total of 60 eyes from 51 patients were finally included in the study, involving nine patients (17.65%) with bilateral cataract surgery. The participants were at a mean age of 69.67 ± 8.51 years, including seven (13.73%) patients aged 50 to 59 years, 18 (35.29%) patients aged 60 to 69 years, 18 (35.29%) patients aged 70 to 79 years, and six (11.76%) patients who were 80 years or older. Basic demographic information and clinical characteristics before surgery are presented in Table 1. The surgery was successful in all patients, and

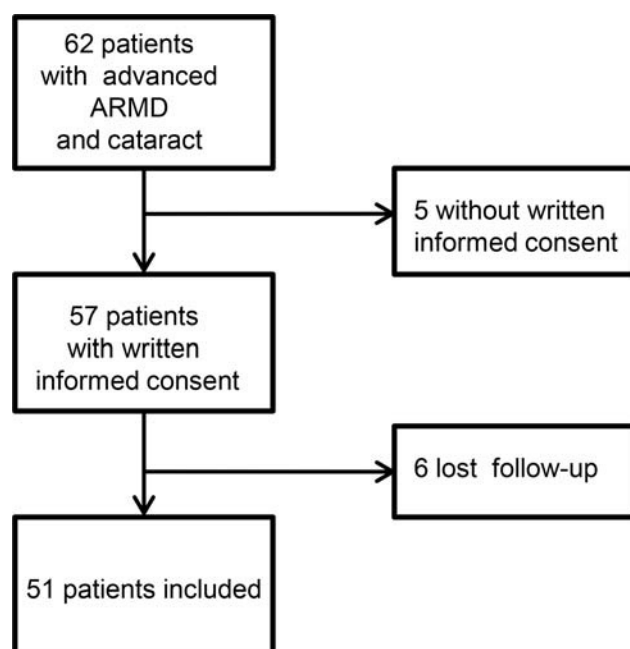


FIGURE 1. Flowchart of the inclusion and exclusion of the participants in the study.

TABLE 1.
Demographic and clinical characteristics of the participants

Characteristics	
No. cases	51
Mean age (SD), yr	69.67 (8.51)
Male, N (%)	22 (56.86)
Education time >12 yr, N (%)	18 (35.29)
No. systemic diseases, N (%)	
0	24 (47.1)
1	17 (33.3)
2	10 (19.2)
Duration of AMD, N (%)	
1–5 yr	19 (37.3)
6–10 yr	22 (43.1)
11–15 yr	10 (19.6)
Bilateral cataract surgery, N (%)	9 (17.6)
Type of AMD, N (%)	
Geographic atrophy	38 (74.5)
Neovascular AMD	13 (25.5)

AMD, age-related macular degeneration; SD, standard deviation.

no severe intraoperative or postoperative complications occurred. No newly developed systemic diseases occurred in any patient during the follow-up. We did not observe any progression of AMD in the patients.

At the 3-month postoperative time point, the BCVA in the operated eye, weighted average BCVA, CLVQOL scores, and utility values from both patients and ophthalmologists increased significantly compared with preoperative states (Table 2). The logMAR BCVA in the operated eye increased by an average of 0.40 ± 0.37 after surgery. However, the improvement in weighted average logMAR BCVA was smaller, with an average of 0.17 ± 0.13 , probably because the less weighted worse eye obtained a greater increase in BCVA after surgery.

The difference in preoperative and postoperative utility value was 0.11 ± 0.07 from the patient's aspect and 0.02 ± 0.05 from the doctor's aspect. The doctors underestimated the influence of the diseases on the patients' QOL and the effect of surgery on the improvement of QOL in the patients (Table 3). In addition, the Pearson correlation coefficient between utility values from the patient's aspect and scores by CLVQOL was 0.498 preoperatively ($p < 0.001$) and 0.441 postoperatively ($p = 0.001$). The Spearman correlation coefficient between utility values from the doctor's

perspective and scores by CLVQOL was 0.457 preoperatively ($p = 0.001$) and 0.253 postoperatively ($p = 0.073$). Although before surgery, utility values from doctors were closely related to CLVQOL scores, the correlation became nonsignificant after surgery. Therefore, in the following analyses, we only use utility values from the patients' aspect for cost-utility analyses but not utility values from the doctor's perspective.

The multiple linear regression analyses indicated that the weighted average BCVA was closely related to the utility values, as well as the education level. Patients with the better-weighted average BCVA and higher education level were more likely to have higher utility values. The change in utility value was only positively correlated with the change in weighted average BCVA (Table 4).

The average costs for examinations, surgery and hospitalization, pharmaceuticals, outpatient services, treatment for complications, and transportation were 748 CNY (119 USD), 8923 CNY (1416 USD), 194 CNY (31 USD), 98 CNY (16 USD), 132 CNY (21 USD), and 147 CNY (23 USD), respectively. The average life expectancy was 13 years in this population. During the remaining lifetime, the patients could obtain 1.17 QALYs by cataract surgery, and costs for each additional QALY gained compared with no treatment were 8835 CNY (1400 USD) (Table 5). Because no guiding official document on the threshold ratio of willingness to pay was admitted in China, we adopted the standard recommendation by the World Health Organization: if the incremental costs per effectiveness ratio are less than three times the gross domestic product (GDP) per capita, it can be regarded as cost-effective; and if the incremental costs per effectiveness are less than the GDP per capita, the intervention can be regarded as highly cost-effective.²⁹ With a 2012 GDP per capita in China of 38,354 CNY (6078 USD),³⁰ we used 115,062 CNY (18,235 USD) per QALY as the threshold ratio of willingness to pay to determine whether the cataract surgery was cost-effective in the participants. According to this threshold, cataract surgery is a cost-effective intervention in patients with bilateral advanced AMD. A cost-effectiveness acceptability curve for cataract surgery in patients with bilateral advanced AMD is presented in Fig. 2. At the threshold of 115,062 CNY (18,235 USD) per QALY, cataract surgery was 100% cost-effective. The probability of being cost-effective reaches 100% when the threshold for willingness to pay is 15,000 CNY (2381 USD) per QALY.

The conclusion was robust in the sensitivity analyses, the costs per QALY ranged from 7045 CNY (1116 USD) to 94,178 CNY (14,925 USD) (Table 6). Altering discount rates did not vary the

TABLE 2.
Change in visual acuity and utility values before and after cataract surgery

	Before surgery	After surgery	Statistical value	p*
BCVA in the surgery eye (N = 60), mean (SD)	1.37 (0.50) (Snellen, 20/469)	0.98 (0.25) (Snellen, 20/191)	Z = -6.104	<0.001
Weighted average BCVA (N = 51), mean (SD)	1.13 (0.22) (Snellen, 20/270)	0.96 (0.17) (Snellen, 20/182)	T = 9.520	<0.001
CLVQOL scores (N = 51), mean (SD)	65.00 (13.63)	75.06 (7.52)	T = -10.319	<0.001
Utility values by patients (N = 51), mean (SD)	0.48 (0.11)	0.59 (0.07)	T = -10.885	<0.001
Utility values by doctors (N = 51), mean (SD)	0.56 (0.08)	0.58 (0.07)	Z = -2.713	0.007

*Wilcoxon signed rank tests were used for examination of BCVA in the surgery eye and utility values by doctors for the non-normal distribution of the differences (Kolmogorov-Smirnov test, $p = 0.002$ and $p = 0.001$, respectively). Paired sample t-tests were used for comparisons between preoperative and postoperative weighted average BCVA, CLVQOL total scores, and utility values by patients.

BCVA, best-corrected visual acuity; CLVQOL, Chinese-version low-vision quality-of-life; SD, standard deviation.

TABLE 3.

Comparisons of UVs between doctors and patients (N = 51)

	Statistical value	p*
Preoperative UV between doctors and patients	Z = -5.835	<0.001
Postoperative UV between doctors and patients	Z = -1.638	0.101
Differences in preoperative and postoperative UV between doctors and patients	T = 9.092	<0.001

*Wilcoxon signed rank tests were used for examination of preoperative UV and postoperative UV between doctor's and patient's aspects for the non-normal distribution of the differences (Kolmogorov-Smirnov test, $p = 0.055$ [the p value was very close to 0.05 and was counted as significant] and $p = 0.022$, respectively). Paired sample t-tests were used for comparisons of differences in preoperative and postoperative UV between doctors and patients.

UV, utility value.

ratios severely. After raising costs by 20 or 50% and decreasing QALYs gained by 20 or 50%, the costs per QALY changed from 10,549 CNY (1672 USD) to 18,177 CNY (2881 USD). Even if we increased costs by 50% and reduced QALYs gained by 50% at the same time, the costs per QALY were still far below the threshold willingness to pay in China. In the model with a 5-year benefit from cataract surgery, which was adopted in other health economic evaluations, the QALY gained was 0.52 and the cost per QALY was 19,901 CNY (3,154 USD). In the more stringent model of 1-year benefit, 0.11 QALYs were gained, and the cost per QALY was 94,178 CNY (14,925 USD), under the threshold ratio as well. Incorporating the costs of posterior capsular opacification treatment, assuming a 53% incidence rate did not greatly affect the costs per QALY compared with baseline.

According to the BCVA of the better-seeing eye, 37 (72.5%) patients had moderate visual impairment and 14 (27.5%) patients had severe visual impairment preoperatively. After cataract surgery, 49 (91.6%) patients were in the moderate visual impairment category and only two (3.9%) patients remained severely visually impaired. The cataract surgery decreased a total of 22.45 DALYs in the 51 patients with both cataract and advanced AMD preoperatively. Costs per DALY averted were 23,271 CNY (3694 USD), which equals the costs per QALY gained because the diseases were not life threatening.

DISCUSSION

In terms of visual acuity, the logMAR BCVA improved by 0.40 ± 0.37 in the operated eye and by 0.17 ± 0.13 in the weighted average of both eyes in this study. The visual outcomes of cataract surgery in patients with advanced AMD have been reported in several studies. The AREDS reported a statistically significant improvement of

1.9 letters in 195 patients with central geographic atrophy and neovascular AMD by cataract surgery operated on during 1992 to 1998³¹; the AREDS 2 presented an improvement of 6.8 letters in 324 patients by surgery performed during 2006 to 2008.⁶ Rosenfeld et al.⁷ observed a mean of 10.4 ± 3.4 letters in patients with concurrent neovascular AMD under ranibizumab injections. Significant improvement in BCVA was also described in other studies associated with visual outcomes of cataract extraction in patients with wet AMD under the treatment of intraocular injection of anti-VEGF drugs, such as ranibizumab or bevacizumab, without observation of progressed AMD and increased need for anti-VEGF injections.^{8,31-34} Compared with these studies, the preoperative BCVA was even worse in our study, and the change in BCVA was greater, which was closer to the results of the study by Mallah et al.,²⁰ with the distance visual acuity increasing from an average of 1.23 (SD, 0.48) to 0.79 (SD, 0.46) in 12 patients with advanced AMD. This could probably be explained by the severity of cataract (greater than grade III, Emery)¹⁴ in our patients preoperatively. The AREDS and the AREDS 2 both indicated that the greater gain in visual acuity was associated with the increasing severity of cataract grade, and severe cataract itself could cause inferior visual acuity.

The study presented an improvement in the utility value from 0.48 to 0.59 in patients' evaluations; however, only an average of 0.02 improvement of the utility value was observed in ophthalmologists' evaluations. Although the preoperative utility values from both patients and doctors correlated with the CLVQOL scores, only the patients' postoperative utility values, but not the doctors' utility values, were significantly associated with CLVQOL scores. Inclusion of the CLVQOL scores proved the validity of calculating QALYs using the utility value from patients' aspect. This is in accordance with previous research that indicated underestimation of the utility values from the doctors' perspective.³⁵

TABLE 4.

Associated factors of preoperative utility value, postoperative utility value, and difference of UV by multiple linear regression analyses*

Associated factor	Preoperative UV		Postoperative UV		Difference in UV
	Preweighted BCVA	Education	Postweighted BCVA	Education	Difference in weighted BCVA
Coefficient	-0.331	0.045	-0.284	0.030	0.219
p	<0.001	0.048	<0.001	0.035	0.006
Adjusted R^2	0.429		0.507		0.126

*The independent variables were permitted with an entry value of $p < 0.05$ and an exit value of $p = 0.10$ under stepwise mode. BCVA, best-corrected visual acuity; UV, utility value.

TABLE 5.

Baseline cost-utility analysis of cataract surgery in patients with coexistent bilateral advanced age-related macular degeneration (bootstrap method, 1000 times)

	QALYs gained in life expectancy	Costs	Costs per QALY
		CNY (USD)	CNY (USD)/QALY
Mean	1.17	10,236 (1,622)	8,835 (1,400)
2.5% CI	0.923849	9,478 (1,502)	6,922 (1,097)
97.5% CI	1.434504	11,107 (1,760)	11,336 (1,797)

CI, confidence interval; CNY, Chinese yuan; QALYs, quality-adjusted life years; USD, U.S. dollar.

Therefore, we conducted further analyses using the utility values from the patients' perspective. The multiple linear regression analysis indicated that the utility values were associated with the weighted average BCVA and the education level. Patients with more than 12 years of education were more likely to have a higher assessment of the utility values than patients with less education time. The reason could be that people with a high education level are probably more conservative and cautious about trading with life years. Although some literature also showed education as an influential factor on utility values, ultimately, the relationship between utility values and education was not determined.^{36,37}

Meanwhile, the change in utility values was solely associated with the change in the weighted average BCVA. In most literature, the utility values were reported to be closely related to BCVA in the better-seeing eye.³⁸ In this study, the weighted average BCVA is composed of 75% from the better eye and 25% from the worse eye, which was also used in another research for a low-vision population.¹⁸ Our results did not contradict with previous research, and we observed that the combination of both eyes influenced the QOL assessed by the patients' themselves. Good vision normally depends on both eyes: patients with unilateral good vision assess lower QOL than patients with bilateral good vision.³⁸ For patients with bilateral severe visual impairment, changes in visual acuity in either of the two eyes could influence their QOL.³⁹ Moreover, patients with bilateral advanced AMD were reported to have worse QOL than patients with unilateral advanced AMD, even after adjusting for visual acuity.⁴⁰ Therefore, it is reasonable that visual acuity in both eyes

could have an impact on the QOL based on patients' preferences, especially when visual acuity in the better eye was poor as well.³⁹

In addition, the improved utility values could also result from the increased peripheral visual acuity, contrast sensitivity, and other visual functions after cataract surgery. In a study by Mallah et al.²⁰ using Daily Living Tasks Dependent on Vision questionnaires, significant improvements were presented in contrast sensitivity, visual function such as watching TV programs, reading road signs, distinguishing a person's features at arm's length, and adjusting to light after being in the dark. We also investigated the participants in our study by the CLVQOL questionnaires. The results demonstrated significant improvement in composite scores, including four subscale scores for general vision and lighting, mobility, psychological adjustment, reading, fine work, and activities of daily living.¹⁵ Although we did not measure the change in other visual functions, such as contrast sensitivity or visual field, we could infer from our study that cataract surgery could improve not only visual acuity but also QOL related to changes in visual function in patients with coexisting advanced AMD.

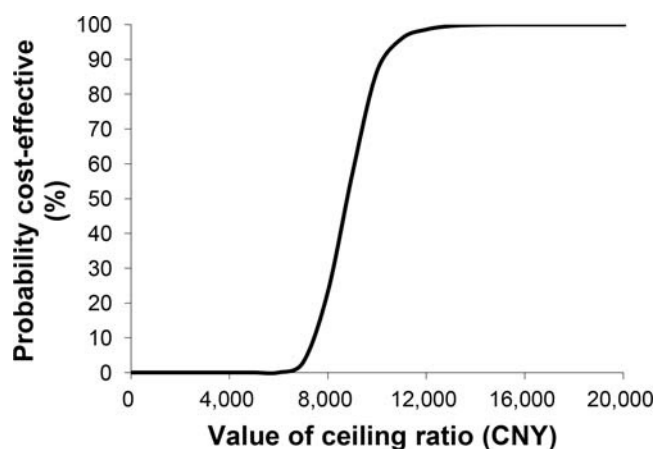
In the further cost-utility analyses, the patients could achieve an additional 1.17 QALYs in their life expectancies with average costs of 10,236 CNY (1625 USD), and the cost per QALY gained was 8835 CNY (1400 USD). The costs per QALY of initial cataract surgery were estimated to be 9 to 1600 USD for developing countries

TABLE 6.

Summary of sensitivity analyses for cost-effectiveness of cataract surgery in patients with coexistent bilateral advanced age-related macular degeneration

Parameters	Costs per QALY
	CNY (USD)/QALY
0% discount	7,045 (1,116)
5% discount	10,251 (1,625)
Costs +20%	10,549 (1,672)
Costs +50%	13,281 (2,105)
QALYs -20%	11,097 (1,759)
QALYs -50%	18,177 (2,881)
Costs +50% and QALYs -50%	27,066 (4,289)
Model with 1-yr benefit	94,178 (14,925)
Model with 5-yr benefit	19,901 (3,154)
Model with PCO treated	9,041 (1,433)
Costs per DALY averted	23,271 (3,694)

CNY, Chinese yuan; DALY, disability-adjusted life year; PCO, posterior capsular opacification; QALYs, quality-adjusted life years; USD, U.S. dollar.

**FIGURE 2.**

Cost-effectiveness acceptability curve for cataract surgery in patients with coexistent bilateral advanced age-related macular degeneration. CNY, Chinese yuan.

and 245 to 2200 USD for developed countries using a fixed model for QALYs gained²⁵ and from 3.5 to 834 USD for developing countries and from 159 to 1356 USD for developed countries using converted utility values from visual acuity data.⁴¹ Compared with the costs per QALY for cataract surgery in developing countries, the ratio was relatively higher for cataract surgery in patients with coexisting advanced AMD probably because of the relatively small improvement in visual outcomes and QOL. However, it is still a cost-effective intervention according to the threshold ratio of 115,062 CNY (18,264 USD) per QALY in China. Sensitivity analyses confirmed the stability of the results. Even in the 1-year benefit model, the cost per QALY was 94,178 CNY (14,925 USD), which is below the threshold ratio. This result means that, even if the benefit of cataract surgery diminishes 1 year after surgery, in the worst-case scenario, it is still cost-effective for those patients to have the surgery.

There are some limitations within this study. The sample size is relatively small, and patients are from the same teaching hospital. It is difficult to collect eligible participants because of the relatively small population of patients with coexisting bilateral advanced AMD and their unwillingness to accept cataract surgery considering the possible poor visual outcomes. In addition, the follow-up period was not long enough to detect the long-term impact of cataract surgery on those patients. Large cohort studies with long follow-up times, such as the Copenhagen City Eye Study, the Beaver Dam Eye Study, and the Blue Mountains Eye Study, indicated the association between cataract surgery and AMD progression.^{3–5} In addition, a recent study discovered that, for patients with exudative AMD under the anti-VEGF treatment, the recurrence of exudative AMD was associated with a shorter exudation-free period before cataract surgery. Therefore, despite the beneficial outcomes from cataract surgery, special cares such as careful preoperative examinations and intensive follow-ups are still needed for patients with concurrent advanced AMD. Future studies with a larger patient population and longer follow-up time are necessary.

In the present study, we demonstrated that cataract surgery could improve both visual acuity and QOL for patients with both age-related cataract and advanced AMD, two common diseases in elderly people. In the long-term, cataract surgery could help patients gain 1.17 QALYs in a lifetime and the costs per QALY were under the threshold of being cost-effective in China. Usually, surgeons and patients were pessimistic about the outcomes of cataract surgery in patients with coexistent advanced macular degeneration, and the present study could provide valuable references for them as to whether to perform the surgery from the aspects of visual acuity, QOL, and health economics.

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