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Impact of Cataract Surgery on Income in Rural Southern China: The SUCCESS Randomized Controlled Trial

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Purpose: Visual impairment from cataracts is closely associated with low income, but trial evidence regarding the impact of surgery on income is lacking. We investigated whether cataract surgery could increase personal income.

Design: A 2-arm, parallel-group, open-label, randomized controlled trial (ClinicalTrials.gov, NCT03020056).

Methods: Persons aged 50 years or older in rural Guangdong, China, with best-corrected visual acuity <6/19 in both eyes due to cataracts were randomly assigned (1:1) to receive surgery within 4 weeks (intervention group), or 1 year later (control group). All participants were interviewed at baseline and end-line regarding demographic characteristics, income, and quality of life.

Results: Among the 292 eligible persons (5.40%, mean age = 74.0 y, 61.0% women) randomly assigned to intervention (n = 146) or control (n = 146) groups, 12 participants (8.22%) in the intervention group and 1 (0.68%) in the control did not receive the allocated intervention. By study closeout, 18 participants (6.16%) were lost to follow-up. The mean 1-year income increase of the intervention group ($2469–$3588; change = $1119) was significantly larger than that of the controls ($2258–$2052; change = $–206), a between-group difference of $1325 (relative increase = 54.0%; 95% CI = $739 to $1911; $P < 0.001$). In multivariable modeling, intervention group membership was associated with greater income increase (β = 1143.2; 95% CI = 582.0 to 1704.3; $P < 0.001$). Greater improvement in best-corrected visual acuity was associated with income increase in univariable modeling (β = 1626.9; 95% CI = 1083.6 to 2170.1; $P < 0.001$).

Conclusions: Cataract surgery substantially increases personal income in rural China, offering a strategy for poverty alleviation. The strong association between increased income and change in visual acuity enhances the biological plausibility of the result.

Key Words: cataract surgery, China, income, quality of life, randomized controlled trial

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INTRODUCTION

Cataract is the leading cause of global blindness and the second-leading cause of moderate and severe visual impairment (MSVI), resulting in a significant loss of economic productivity and reduced quality of life (QoL).[1] The latest Global Burden of Disease study indicates that the number of people with blindness and MSVI reached 43.3 and 295 million, respectively, in 2020.[2] Visual impairment is closely associated with lower socioeconomic status (SES).[3] Research has consistently shown that lower SES is a powerful determinant of poor health-related outcomes and is one of the main causes of health disparities between different regions and populations.[4] As a corollary of this, disease treatment and recovery can potentially improve individual SES, generating a virtuous circle of financial success and better health outcomes.

Cataract-related vision impairment can be effectively corrected only by surgery, shown to be among the most

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X.T., Y. Zheng, W.H., and Y.L.: conceived the study. X.T., Y. Zheng, Y. Zeng, and W.H.: designed the protocol. L.L., N.C., X.H., and X.L.: revised the protocol. X.T., X.H., X.Q., D.W., B.L., and S.H.: conducted the study. X.T., X.H., N.C., Y. Zhu., C.C., and J.Z.: drafted the paper. H.D.: provided help with the economic analysis and interpretation. L.J.: provided the statistics-related design, with some technical input from N.C., Y.L., M.H., N.C., L.L., and H.L.: provided critical revisions to the paper.

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cost-effective interventions in health care, ranking, for example, ahead of various malaria treatments and oral rehydration therapy.[5] The demand for cataract surgery has been expanding worldwide due to the aging and growing global population.[6] It has been suggested that cataract surgery may not only restore vision but also increase income at the household level and improve QoL among beneficiaries.[7,8] This is of pragmatic importance given that in rapidly aging societies, elderly people are also expected to be productive at work, and delays in retirement age are being considered in many countries.[9,10] People with improved visual function are more likely to engage in income-earning activities and have a lower risk of accidents and unintentional injuries in the workplace.[11,12] By extension, limited access to eye care services contributes to untreated impairment, which leads to further unemployment and economic loss.[13–15] Visual impairment can also cause depression, leading to further reduced productivity and unemployment.[16]

Documenting the impact of cataract surgery on income can help governments to weigh the benefits of free surgical programs for low-income beneficiaries, assessing their place in overall health planning.[17] Existing studies investigating the effects of cataract surgery on income are few and suffer from confounding and cohort effects due in part to the lack of prior randomized trials.[8,12] The extent, to which cataract surgery improves income and whether such benefits are constrained by age, sex, or other limitations have important implications for public health planning.

China is a developing country with the largest number of persons visually impaired by cataracts in the world, with 2.95 million blind and 15.2 million with MSVI in 2019.[18] Despite the recent increase in China's cataract surgical rate and advances in surgical techniques, there is a substantial backlog of persons visually impaired by unoperated cataracts, especially in rural areas.[18] The China Nine-Province Survey indicated that 37.3% of rural-dwelling persons with cataract-related severe visual impairment or blindness did not receive surgery, with the greatest unmet need among the elderly, women, and the less educated.[19] We conducted a randomized controlled trial to investigate the impact of cataract surgery on income and QoL in rural China to inform decisions by policymakers on addressing this problem.

METHODS

Study Design and Sites

The SUrgery for Cataract Creates Economic and Social Solutions (SUCCESS) study was a parallel-group, open-label, randomized controlled trial carried out in rural areas of Huidong County, Guangdong Province, Southern China. The study was approved by the ethics committee of the Zhongshan Ophthalmic Center at Sun Yat-sen University, Guangzhou, China (2016KYYJ007). Written informed consent was obtained from participants at enrollment. The study adhered to the tenets of the Declaration of Helsinki and was registered at ClinicalTrials.gov (NCT03020056) on January 13, 2017, with the first participant enrolled on January 16, 2017. Participant enrollment was completed on May 26, 2017, and the study was completed on June 29, 2018. A completed "Standard Protocol Items: Recommendations for Interventional Trials" checklist is available (Supplementary Digial Content 1, http://links.lww.com/APJO/A251), and the protocol (Supplementary Digial Content 2, http://links.lww.com/APJO/A252) and full data set are available online (at http://www.qub.ac.uk).

Huidong County is located in southeastern Guangdong, with a population of 933,700 in 2017, 41.3% being rural dwellers.[20] The annual rural per capita disposable income in 2017 ($2725) was substantially lower than that of Guangdong province ($4638) in the same year.[21]

Study Participants and Enrollment

Enrollment criteria included: age 50 years or older, with best-corrected visual acuity (BCVA) of <6/19 due to age-related cataracts in both eyes (the better eye $\geq$6/300). Persons were excluded for: (1) history of other ocular diseases leading to visual impairment; (2) medical need for immediate surgery; (3) presence of systemic disease hindering physical activity; and (4) inability to provide informed consent.

Ophthalmologists at the Huidong People's Hospital conducted cataract outreach screenings at township health centers or village clinics and patients fulfilling inclusion criteria were invited to participate in the study. Two trained nurses introduced the study to eligible patients and offered participation. All participant expenses related to cataract surgery, including preoperative laboratory examinations, transportation to a hospital, and postoperative medications and examinations, were jointly covered by their health insurance, government subsidies, and research funds. Participants had no out-of-pocket expenses for study surgery.

Sample Size, Randomization, and Masking

Assuming a baseline mean annual income of $2500 based on data from an initial survey, a sample size of 139 participants per group, allowing for a 25% loss to follow-up, would be sufficient to detect a 7.5% difference in 12-month income change between the intervention ($375, 15%) and control ($188, 7.5%) group members, with a common SD of $415, at a 2-sided significance level of 0.05 and power of 90%. The sample size was calculated using PASS 11.0 (NCSS, LLC, US).

The trial statistician (L.J.) prepared a computer-generated randomization list with an allocation ratio of 1:1 and a block size of 4. To minimize allocation bias, randomization was conducted after confirmation of eligibility. Participants were randomly assigned to receive cataract surgery in the worse-seeing eye within 4 weeks (intervention group) or to be added to a waiting list to receive surgery 1 year later (control group). Cataract surgery was performed in the worse-seeing eye for participants in the intervention group to maximize the benefit of surgery. Participants in the control group were informed of their cataract severity and were also told that they could seek paid cataract surgery at any time outside of the study. For practical reasons, this study was open-label: participants were informed of the overall study design and their treatment arm assignment.

Interventions

Cataract surgeries were carried out at the Huidong People's Hospital by 2 experienced ophthalmologists (S.H. and B.L.) from Zhongshan Ophthalmic Center. Routine

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preoperative examinations, included assessment of BCVA and intraocular pressure, slit-lamp biomicroscopy, fundoscopy, keratometry, ocular ultrasonographic *A* scan and *B* scan, laboratory examinations for various blood-borne pathogens, chest x-ray, and electrocardiogram, were conducted at the local hospital per standardized protocol.

Manual small-incision cataract surgery was performed for patients with lens nuclear hardness greater than grade 4 on the Emery-Little classification system,[22] corneal endothelial cell density <1000/mm^2, or cataract in the hypermature stage. Phacoemulsification surgery was performed for all other participants. All study participants underwent monofocal intraocular lens implantation at the time of surgery. Follow-up examinations were scheduled at 1 week, 1 month, 3 months, 6 months, and 1 year after surgery, and included assessment of BCVA and intraocular pressure, slit-lamp biomicroscopy, and examination of the fundus without pupil dilation. To improve participant compliance with examinations, free artificial tear eye drops, an over-the-counter treatment for the common condition of dry eye, were provided monthly to the intervention group, and antioxidant eye drops (Phacolin, Zhongshan Ophthalmic Center) to the controls.

Participants and their families were interviewed face-to-face in their homes by trained interviewers in the local Hakka dialect at baseline and 1 year after the study intervention to collect data on demographic characteristics, household SES, and health-related and vision-related QoL. The interview process and living conditions were recorded by video with the participants' permission. BCVA was measured by trained nurses at both baseline and follow-up using a logarithm of the minimum angle of resolution (logMAR) tumbling *E* chart (Precision Vision) under ambient lighting at 4 meters. The logMAR visual acuity for each eye was recorded for analysis. The completeness of the study data was checked daily by 2 researchers (X.Q. and X.T.). Data were double-entered into Excel (Microsoft) and were analyzed by the trial statistician (L.J.), masked to the study design and treatment assignments.

Outcomes

The primary study outcome was the difference between the 2 study groups in change in mean annual self-reported personal income from work between baseline and 1 year after the study intervention. A household SES questionnaire designed by the authors and comprising 18 questions was used (Supplementary Digital Content 3, http://links.lww.com/APJO/A253) and included questions on occupation, education, marital status, number of family members, personal and household income, paid and unpaid working hours, family debts, ownership of the real estate, family/personal expenses, and family members' time and expenses caring for the index cataract patient. Consistency of the same participant's responses at different time points and by different interviewers was checked for all questions.

Annual personal income from work is a measurement of the value of time spent on productive activities. Productive activities are defined as: (1) paid work (salary from paid employment or income from self-employment or agriculture work); (2) informal income-generating activities (eg, trash pickup, occasional commercial motorcycle taxi transport); and (3) unpaid productive activities (eg, subsistence production, family farm work, domestic activities, and childcare). It is important to include unpaid work because all household members regardless of age commonly contribute to the basic needs of a household in rural low-income settings, such as China. Direct employment opportunities are limited in these settings, particularly for the elderly who are most affected by cataracts, and the economic importance of unpaid activities is well recognized.[23,24] In developing countries, income in kind generated by these nonmarket activities contributes a sizeable share of the goods and services actually consumed by households. In our sample, over 90% of participants had no income from paid work.[25]

The value of time spent on unpaid productive activities is derived from the self-reported number of hours of unpaid work multiplied by the minimum hourly income in Huidong County in 2017, as reported by the Ministry of Human Resources and Social Security of the People's Republic of China.[26] Total annual personal income is then calculated using the following equation: Annual Personal Income = Self-Reported Income From Paid Work + Daily Unpaid Work Time (in hours)×13.3 CNY/hour×250 days.[26] The yearly unpaid work time for each participant was calculated as 250 days, derived from a 365-day year by subtracting 104 weekend days and 11 legal holidays. An exchange rate of 6.61 [obtained from the Chalü website (https://chl.cn/?usd-2020) on October 10, 2020] was used to convert incomes reported in CNY to USD.

Secondary study outcomes included QoL, both health-related (Chinese version of the European QoL questionnaire, EQ-5D-5L)[27] and vision-related (Chinese version of Catquest-9SF).[28] The total score of the 5 dimensions on the EQ-5D-5L (range = 5–25 points) was used for analysis, and a lower score indicated better QoL. Self-rated health was, in addition, assessed using a visual analog scale, with scores ranging from 0 (worst imaginable health state) to 100 (best imaginable). The Catquest-9SF questionnaire[28] includes 7 questions regarding daily activities and 2 questions on difficulties and satisfaction with vision, each rated from 1 (very great difficulty) to 4 (no difficulty).

Statistical Analyses

Continuous variables with normal distribution were expressed as means (SD) and categorical variables as frequency (percentage). logMAR BCVA in the better-seeing eye at baseline demonstrated a non-normal distribution and was characterized by the median [interquartile range (IQR)]. A Snellen equivalent value is presented for reference throughout. The normality of continuous data was checked using the Shapiro-Wilk test and histograms.

The intention-to-treat (ITT) principle was followed in calculating the unadjusted difference and 95% CI for the primary and secondary outcomes. Linear regression modeling was used in the ITT analyses for all comparisons. The adjusted between-group difference in the primary outcome was estimated using an ITT analysis by fitting multivariable linear regression models controlling for other potential determinants. To calculate the change in logMAR BCVA, vision in the operative eye for participants in the intervention group and in the better-seeing eye for participants in the control

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group was utilized. For participants who did not receive allocated cataract surgery in the intervention group, BCVA from the better-seeing eye was used instead. A univariable regression analysis was performed first, and age, sex, and all variables with P <0.20 in the univariable analysis were included in the multiple regression model. However, cataract surgery was hypothesized to exert its impact on the main outcome entirely through its effects on improving vision. Thus, it was not considered appropriate to include the change in vision in the final multivariable model, though it was highly significant in the univariable analysis.

All statistical analyses were performed using Stata 16.1 (StataCorp), and a 2-sided P value <0.05 was considered statistically significant.

RESULTS

Among 5404 persons aged 50 years or older undergoing screening, 292 (5.40%) met all eligibility criteria and were enrolled (Fig. 1). All participants completed the baseline interview and were randomly assigned to the intervention (n = 146, 50.0%) or control (n = 146, 50.0%) groups. In the intervention group, 12 participants (8.22%) did not receive the allocated cataract surgery, including 9 (75.0%) who completed follow-up, 1 (8.33%) who died, and 2 (16.7%) who refused the follow-up visit. Of the 134 intervention group participants receiving allocated cataract surgery (91.8%), 3 (2.24%) died, 1 (0.75%) refused follow-up, and the remaining 130 (97.0%, 89.0% of original allocated participants) completed the study. In the control group, 1 participant (0.68%) received cataract surgery contrary to allocation and completed follow-up. Of the remaining 145 participants (99.3%), 2 (1.38%) died, 9 (6.21%) refused the follow-up visit, and 134 (92.4%, 91.8% of original allocated participants) completed the study. At the study closeout, data were missing for a total of 18 participants (6.16%), and 274 persons (93.8%) were included in the ITT analyses (Fig. 1).

The baseline characteristics of participants are shown in Table 1. The mean (SD) age of participants was 73.0 (7.54) years in the intervention group and 74.9 (8.25) years in the control group. There were 66 (45.2%) and 48 (32.9%) men in the intervention and control groups, respectively. The median logMAR BCVA in the better-seeing eye was 0.65 (IQR = 0.60–0.80) (Snellen equivalent 6/27, IQR = 6/38–6/24) in the intervention group and 0.60 (IQR = 0.60–0.80) (Snellen equivalent 6/24, IQR = 6/38–6/24) in the control group. Over 80% of participants in both groups were farmers, and <10% had an education level of middle school or higher.

Annual income in the intervention group increased from $2469 to $3588 between baseline and 1 year after surgery. This increase of $1119 (95% CI = 593 to 1645) was greater than that in the control group [$2258–$2052, change of $–206 (95% CI = –457 to 45)]. The between-group difference [$1325 (95% CI = 739 to 1911); $P < 0.001$] was equivalent to a 54.0% relative increase in income (Table 2). The Alpha index for participants' responses about income at different time points and by different interviewers was higher than 0.8, indicating good consistency.

In univariable regression models, factors associated with increased income included intervention group membership (β = 1325.4, $P < 0.001$), change in BCVA (β = 1626.9, $P < 0.001$), employment other than as a farmer (β = 1171.7, P = 0.008), living in a block rather than a tile-roofed house (β = 788.1, P = 0.022), larger house size (>90 vs ≤ 60 m^2: β = 850.3, P = 0.030), greater monthly medical expenses for cataract ($\$ > 8$ vs $0: β = 4033.3, $P < 0.001$), and greater family time spent caring for the index participant (>0 to ≤ 2 h vs 0 h: β = 1398.3, P = 0.002; >2 vs 0 h: β =

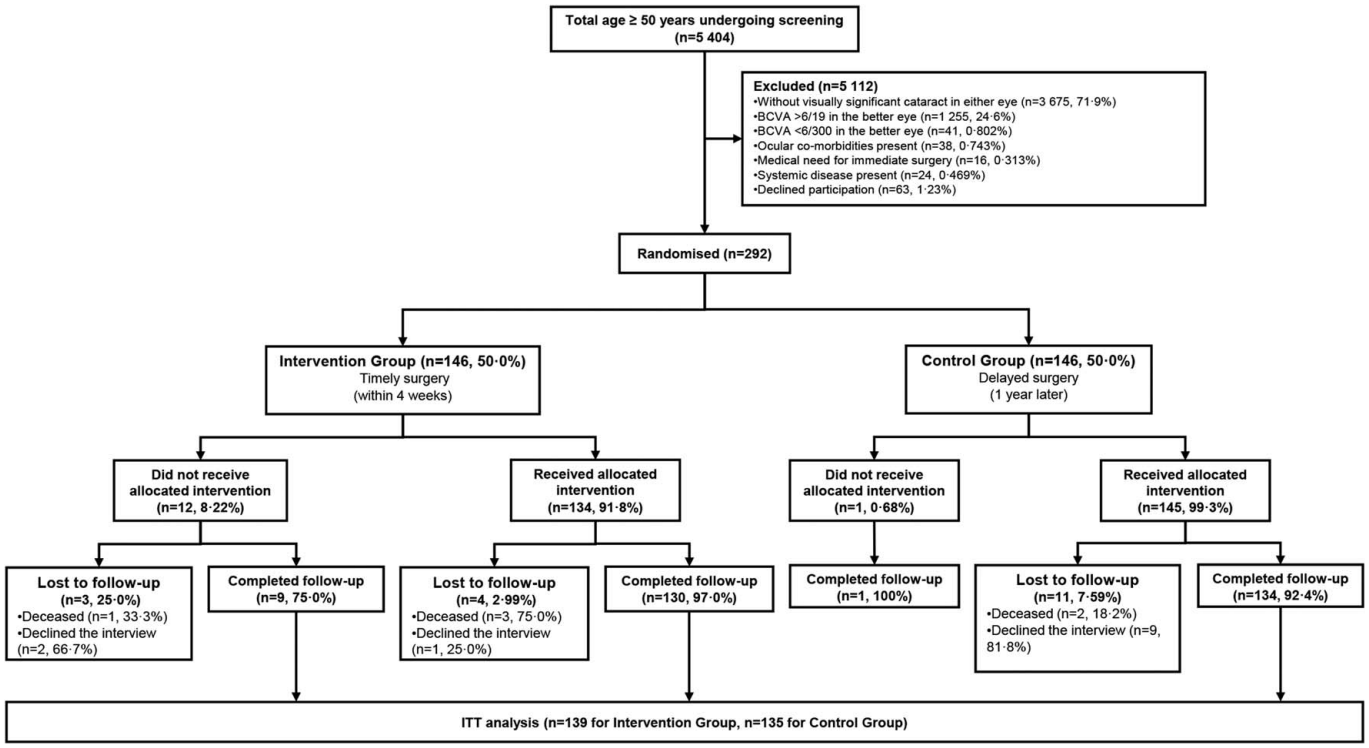

FIGURE 1. Flowchart of participant enrollment, allocation, and analysis. BCVA indicates best-corrected visual acuity; ITT, intention-to-treat.

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TABLE 1. Baseline Characteristics of Study Participants (N = 292)

Characteristics	Intervention Group (n = 146, 50%)	Control Group (n = 146, 50%)
Age (y); mean (SD)	73.0 (7.54)	74.9 (8.25)
Sex (M)	66 (45.2)	48 (32.9)
BCVA in better eye, logMAR; median (IQR) Snellen equivalent	0.65 (0.60–0.80) 6/27 (6/24–6/38)	0.60 (0.60–0.80) 6/24 (6/24–6/38)
Education status		
No formal education	56 (38.4)	68 (46.6)
Primary school	78 (53.4)	69 (47.3)
Middle school or higher	12 (8.22)	9 (6.16)
Working as a farmer	126 (86.3)	124 (84.9)
Marital status; married	96 (65.8)	89 (61.0)
No. family members in the house		
≤4	82 (56.2)	80 (54.8)
>4–≤8	62 (42.5)	60 (41.1)
>8	2 (1.37)	6 (4.11)
No. family members working		
0	51 (34.9)	53 (36.3)
>0–<3	80 (54.8)	75 (51.4)
≥3	15 (10.3)	18 (12.3)
House type		
Tile-roofed house	36 (24.7)	46 (31.5)
Block	110 (75.3)	100 (68.5)
Area of house (m^2)		
≤60	33 (22.6)	34 (23.3)
>60–≤90	43 (29.5)	40 (27.4)
>90	70 (48.0)	72 (49.3)
Family-owned or operated land area (m^2)		
0	30 (20.6)	34 (23.3)
>0–≤1333	28 (19.2)	35 (24.0)
>1333	88 (60.3)	77 (52.7)
Current family debt*		
0	84 (57.5)	89 (61.0)
>0–≤1513	23 (15.8)	27 (18.5)
>1513–≤7564	27 (18.5)	23 (15.8)
>7564	12 (8.22)	7 (4.79)
Index participant's monthly expenses*		
<30	57 (39.0)	67 (45.9)
≥30–≤76	68 (46.6)	57 (39.0)
>76–<121	12 (8.22)	16 (11.0)
≥121	9 (6.16)	6 (4.11)
Family monthly expenses*		
≤151	68 (46.6)	73 (50.0)
>151–≤303	40 (27.4)	39 (26.7)
>303	38 (26.0)	34 (23.3)
Monthly medical expenses for cataract*		
0	58 (39.7)	59 (40.4)
>0–≤8	84 (57.5)	84 (57.5)
>8	4 (2.74)	3 (2.05)
Family annual income*, median (IQR)	6115 (2003–10439)	4491 (1337–9867)
Daily time spent caring for index cataract, n (%) participant, hours		
0	38 (26.0)	55 (37.7)
>0 to ≤2	32 (21.9)	21 (14.4)
>2	76 (52.1)	70 (48.0)

*1 = 6.61 CNY.

BCVA indicates best-corrected visual acuity; IQR, interquartile range; logMAR, logarithm of the minimum angle of resolution.

Data are expressed as n (%) unless otherwise stated.

TABLE 2. Effect of Cataract Surgery on Participants' Annual Personal Income ($) From Work (Unadjusted Model Following ITT)

	Baseline Annual Personal Income From Work		Postintervention Annual Personal Income From Work Mean (SD)		Change in Income		Between-Group Difference in Change in Income
	n	Mean (SD)	n	Mean (SD)	n	Mean (95% CI)	Mean (95% CI)
Intervention group	146	2378 (2037)	146	3588 (3169)	146	1131 (625, 1638) $P < 0.001$*	1285 (710, 1860) $P < 0.001$†
Control group	146	2217 (1787)	146	2052 (1595)	146	−154 (−433, 125) $P = 0.277$*	—

ITT indicates intention-to-treat.

*The P value was calculated from the combined results of linear regression analysis for paired differences based on multiple imputed data sets.

†The P value was calculated from the combined results of linear regression analysis for group differences based on multiple imputed data sets.

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TABLE 3. ITT Analysis: Linear Regression Model of Potential Predictors of Change in Annual Self-Reported Personal Income ($) From Work

Characteristics	Univariable Analysis (N = 292)*,‖		Multivariable Analysis (N = 292)†,‖	
	β (95% CI)	*P*	β (95% CI)	*P*
Intervention group	1285.0 (710.5, 1859.9)	< 0.001	1120.3 (568.1, 1672.6)	< 0.001
Younger age (y); age effect in the control group§	39.2 (0.95, 77.4)	0.045	−27.4 (−79.5, 24.6)	0.300
Younger age (y); age effect in the intervention group§	—	—	79.9 (28.1, 131.8)	0.003
Younger age × group interaction§	—	—	107.4 (34.7, 180.1)	0.004
Sex (M)	−28.2 (−634.0, 577.6)	0.927	339.1 (−254.0, 932.2)	0.261
BCVA improvement; logMAR‡	1481.7 (965.6, 1997.9)	< 0.001	—	—
Employment other than the farmer	1097.6 (267.0, 1928.2)	0.010	826.9 (1.98, 1651.7)	0.049
Married	488.8 (−128.3, 1105.9)	0.120	310.3 (−331.2, 951.9)	0.342
House type				
Tile-roofed house	Reference	—	Reference	—
Block	758.4 (106.9, 1409.9)	0.023	417.5 (−187.5, 1022.6)	0.175
Area of participant's house (m^2)				
≤ 60	Reference	—	Reference	—
> 60– ≤ 90	558.1 (−290.5, 1406.7)	0.197	738.4 (−119.5, 1596.3)	0.091
> 90	801.7 (47.2, 1556.1)	0.037	308.0 (−419.8, 1035.8)	0.406
Monthly medical expenses for cataract ($)				
0	Reference	—	Reference	—
> 0– ≤ 8	530.8 (−64.2, 1125.7)	0.080	497.8 (−76.0, 1071.7)	0.089
> 8	4007.4 (2121.4, 5893.5)	< 0.001	3304.5 (1493.5, 5115.5)	< 0.001
Time spent caring for index cataract participants (h)				
0	Reference	—	Reference	—
> 0– ≤ 2	1336.7 (483.9, 2189.4)	0.002	1034.5 (228.1, 1840.9)	0.012
> 2	1166.1 (505.6, 1826.5)	0.001	870.0 (222.3, 1517.8)	0.009

BCVA indicates best-corrected visual acuity; ITT, intention-to-treat; logMAR, logarithm of the minimum angle of resolution.

*All variables in Table 1 were included in the univariable regression analysis and only results for age, sex, and variables with $P < 0.20$ were presented.

†Including age, sex, and all variables with $P < 0.20$ in the univariable analysis.

‡The change in best-corrected visual acuity was calculated as the logMAR visual acuity at baseline minus that at 1-year follow-up, this was not included in the multivariable model given that the surgical intervention was expected to increase income purely through its impact on visual acuity, and including both intervention group and visual acuity change in the model was inappropriate.

§Age was centralized by subtracting the mean of age.

‖The *P* value was calculated from the combined results of linear regression analysis based on multiple imputed data sets.

1194.7, $P = 0.001$; Table 3). In multivariable regression models, variables significantly associated with a greater increase in annual income included intervention group membership (β = 1143.2; 95% CI = 582.0 to 1704.3; $P < 0.001$), employment other than as a farmer (β = 869.1, 95% CI = 25.9 to 1712.4; $P = 0.043$), greater baseline monthly medical expenses for cataract ($ > 8 vs $0: β = 3295.7; 95% CI = 1480.1 to 5111.3; $P < 0.001$), and more baseline time spent by family members caring for the index cataract patient (> 0 to ≤ 2 vs 0 h: β = 1037.6; 95% CI = 207.8 to 1867.5; $P = 0.014$; > 2 vs 0 h: β = 905.6; 95% CI = 255.5 to 1555.8; $P = 0.007$). In addition, younger age was associated with a larger increase in income (β = 81.9; $P = 0.002$) in the intervention group (Table 3).

The total health-related QoL score on the EQ-5D-5L decreased (improved) in the intervention group (–2.30; 95% CI = –2.85 to –1.75) but worsened among the controls (2.80; 95% CI = 2.20 to 3.40; intergroup difference: –5.10; 95% CI = –5.91 to –4.29; $P < 0.001$; Table 4) during the 1-year study follow-up. Health score on the visual analog scale in the intervention group increased from 57.5 to 74.2 during follow-up, and the extent of the increase (16.7; 95% CI = 14.5 to 18.9) was greater than that in the control group [57.7 to 57.9; increase 0.22 (95% CI = –2.00 to 2.45); intergroup difference 16.5 (95% CI = 13.4 to 19.6; $P < 0.001$); Table 4]. The Catquest-9SF score in the intervention group increased (improved) by 7.59 (15.8 to 23.4; 95% CI = 6.80 to 8.38), which was significantly greater than the control group [16.3 to 15.1, increase = –1.24 (95% CI = –1.86 to –0.62); intergroup difference = 8.83; 95% CI = 7.82 to 9.83; $P < 0.001$].

DISCUSSION

In the SUCCESS trial, we observed a significant relative 54.0% increase in self-reported annual personal income from work among elderly rural Chinese participants with visually significant cataracts randomized to receive timely cataract surgery as compared with the controls randomized to receive deferred surgery. This seems to be largely due to improved vision after cataract surgery. Intervention group membership was also associated with greater improvement in health-related and vision-related QoL. These results collectively suggest that timely cataract surgery can be an effective poverty alleviation strategy in this setting.

We systematically searched for studies investigating the impact of cataract surgery on SES published in English between database inception and March 3, 2021, in MEDLINE, EMBASE, SCOPUS, and the Cochrane Central Register of Controlled Trials database (full search terms in Supplementary Digital Content 4, http://links.lww.com/APJO/A254). No previous randomized controlled trials were identified. The small number of existing nonrandomized studies

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TABLE 4. ITT Analysis: Effect of Cataract Surgery on Health and Vision-Related QoL (Unadjusted Model)*

	Intervention Group			Control Group			
	Baseline Mean (SD)	Postintervention Mean (SD)	Change (95% CI)*	Baseline Mean (SD)	Postintervention Mean (SD)	Change (95% CI) *	Between-Group Difference of Change (95% CI) ‡
Intention-to-Treat	146	146	146	146	146	146	292
EQ-5D-5L							
Total score of 5 dimensions	10.8 (3.01)	8.44 (2.76)	−2.34 (−2.89, −1.80) $P < 0.001$†	10.2 (3.17)	13.0 (3.01)	2.82 (2.22, 3.41) $P < 0.001$†	−5.16 (−5.96, −4.36) $P < 0.001$‡
Health score	56.9 (12.5)	74.1 (9.65)	17.2 (15.0, 19.3) $P < 0.001$†	57.9 (13.5)	58.0 (7.02)	0.15 (−1.99, 2.30) $P = 0.889$†	17.0 (14.0, 20.0) $P < 0.001$‡
Catquest-9SF score	15.8 (3.33)	23.3 (4.03)	7.51 (6.73, 8.30) $P < 0.001$†	16.3 (3.32)	15.1 (3.12)	−1.22 (−1.85, −0.60) $P < 0.001$†	8.74 (7.74, 9.74) $P < 0.001$‡

ITT indicates intention-to-treat; QoL, quality of life.

*Lower EQ-5D-5L total score shows a better quality of life; Higher health score shows a better quality of life; Higher Catquest-9SF score shows better visual function.

†The P value was calculated from the combined results of linear regression analysis for paired differences based on multiple imputed data sets.

‡The P value was calculated from the combined results of linear regression analysis for group differences based on multiple imputed data sets.

have suggested that cataract surgery improves household economic status, economically productive activity, and QoL.[7,8,12] In 2014, the observational VISIONARY study in Vietnam reported significantly improved health-related QoL, and increased household-level work participation, income, and asset ownership 12 months after cataract surgery.[8] In 2012, Finger et al[7] reported that cataract surgery led to increased QoL, monthly household income, income-generating activity, and the number of working household members among recipients in rural India. The Cataract Impact Study in Kenya, Bangladesh, and the Philippines found that QoL, household per capita expenditure, and time spent on productive activities increased significantly 1 year after cataract surgery, with benefits persisting at 6 years.[12]

However, these observational studies were susceptible to cohort effects,[29] which could explain all or part of the observed economic improvements due to intercurrent trends affecting the population at large.[7,8] Our review identified no prior randomized controlled trials investigating the relationship between cataract surgery and income among visually impaired persons. Such studies are challenging to perform in low-resource areas where poverty alleviation strategies are most relevant. Medical resources may be limited, and lack of knowledge and other economic and cultural barriers may adversely affect both participation and follow-up.

In rural China, it is common that elderly persons still cannot find or maintain paid work even with improved vision after cataract surgery, so the SUCCESS trial considered both incomes from paid productive activities plus the value of time spent on unpaid productive activities in evaluating the main study outcome. The economic contribution of unpaid productive activities is well recognized, particularly in rural, low-income settings, where direct employment opportunities are limited for the elderly.[11,24]

In this setting, more than 90% of self-reported income was generated from unpaid productive activities, thus not readily susceptible to external verification. The necessity of relying on self-report for our main outcome and the impracticality of masking the intervention means that the possibility of placebo effects cannot be excluded. Social desirability bias may also exist, whereby those who received the surgery might exaggerate their responses to please the interviewer as they were pleased with the surgery's effects on their QoL. However, the very strong association between self-reported increase in income and postoperative increase in visual acuity makes it far less likely that either placebo effects or reporting bias could explain the observed increase in income as neither of these would be expected to produce such an association.

Methodological questions arise over the appropriate methods for imputing a monetary value to activities that are not the object of monetary transactions,[25] but most of the previously used common approaches are not well suited to evaluating unpaid work in rural, low-income settings.[30,31] Assigning an imputed value equal to the wage paid to workers performing similar activities is problematic because productivity circumstances in market enterprises are different from those prevailing in the household, and thus the imputed wages will overestimate the monetary value of nonmarket productive activities. Similarly, imputing wages based on setting the value of one hour of unpaid work equal to the

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hourly wage rate of the person performing the unpaid work is inappropriate for elderly persons in rural China, for whom there are few employment opportunities, and, therefore, the equivalent market value of their time cannot be estimated.

The use of average wages as a proxy for unpaid work when individuals have no market wage also presents difficulties for this elderly cohort with very low education levels, as average wages would likely lead to an overestimation of the value of their unpaid work. The minimum hourly wage used in this study provides a conservative, lower-bound estimation of the monetary value of unpaid work conducted by elderly persons with low education levels in rural China.

Nonfarm participants were found to have larger income increases than farmers. Cataract surgery seems to increase income mainly through improved vision, and many other occupations and types of work (such as construction and sewing) may be more dependent on vision than farming. Unsurprisingly, greater monthly medical expenses (eg, hiring nursing people) for cataracts were associated with larger income increases. These participants likely had more severe cataracts and poorer vision and could thus benefit more from surgery. Greater family time caring for the index cataract patient may have similarly functioned as a marker of more severe impairment, perhaps explaining the observed greater associated income gain.

The significantly lower income increases among older participants in the intervention group may have been due to poorer general health status, mobility, and productivity. This result suggests that to maximize the increase in personal income, cataract surgery should be performed as early as possible for those in need. The Chinese government is currently considering a delay in the retirement age for both sexes,[32] in which case policy and financial support to guarantee timely access to high-quality cataract surgery are important to improve the productivity of affected persons.

Consistent with previous studies, we found that cataract surgery was associated with improved health- and vision-related QoL.[27,33–35] This is important as both socioeconomic and QoL effects should be taken into consideration for health interventions. The Catquest-9SF used in this study is a short form of the Catquest questionnaire,[14] designed to assess cataract patients' perceived difficulties in daily life, and has been validated in Chinese patients with cataracts.[28] Participants who received timely cataract surgery achieved greater QoL improvement than those with deferred surgery, which may be attributed to better vision, higher income, and improved social engagement.[36]

Strengths of the SUCCESS trial include the design of the randomized controlled trial, thorough evaluation of economic status through an assessment of both paid and unpaid productive activities, and inclusion of health- and vision-related QoL as an outcome. Limitations of the study must also be addressed. First, the study only included participants from one rural county in Southern China, and cataract patients with BCVA <6/300 in the better-seeing eye were not included due to ethical concerns about deferring their surgery. Thus, caution should be taken in extrapolating the study conclusions to other settings or patient groups. However, it should be noted that poor, rural areas are exactly the setting in China, in which the poverty alleviation impact of cataract surgery is most relevant. Secondly, the sample size was relatively small; however, our calculations show it was adequately powered, and in fact, the trial detected a highly significant difference. Thirdly, data were missing for 18 participants (6.16%) who were lost to follow-up. Further imputation of the missing values for these 18 participants revealed the same study conclusion. Lastly, the value of time spent on unpaid productive activities was calculated from data on unpaid work time collected on a single random day. The representativeness of these data is uncertain, and there is also a possibility of recall bias.

Despite its limitations, the SUCCESS trial provides high-quality evidence that early provision of cataract surgery is a practical and effective poverty alleviation strategy in rural China. These findings are further supported by the biological plausibility conferred by the strong observed association between change in income and change in vision. Our findings highlight the potential economic and quality-of-life benefits of providing broad and timely access to cataract surgery in low and middle-income countries.

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