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CATARACT SURGICAL COVERAGE AND VISUAL ACUITY OUTCOMES IN RURAL CHINA IN 2014 AND COMPARISONS WITH THE 2006 CHINA NINE-PROVINCE SURVEY

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Abstract

Purpose—Estimate surgical coverage of cataract-related vision impairment and blindness and visual acuity outcomes in operated eyes in rural China in 2014 with comparisons with the 2006 Nine-Province Survey.

Design—Population-based, cross-sectional study.

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Methods—Geographical cluster sampling was used in randomly selecting residents from a rural county or semi-rural district within 9 provinces: Beijing, Jiangsu, Guangdong, Heilongjiang, Jiangxi, Hebei, Ningxia, Chongqing and Yunnan. Persons 50 years of age or older were enumerated through household visits and invited to examination sites for visual acuity testing and ocular examination. Surgical coverage and visual acuity outcomes in 2014 were compared with data from the 2006 survey.

Results—Among 51,310 examined persons, surgical coverage among those presenting with cataract-related severe visual impairment or blindness (<20/200) was 62.7% overall, ranging from 43.4% to 83.6% across the 9 study sites. Un-operated cataract was significantly associated with older age, female gender, and lack of education. Visual acuity outcomes ≥20/63 in cataract operated eyes was 62.2% overall, ranging from 51.6% to 78.6%, and 75.2%, ranging from 67.1% to 81.5%, with best corrected visual acuity. As a proportional percentage of cataract surgical coverage in 2006, overall surgical coverage increased by 81.4% during the 2006–2014 interval, and by 110% when adjusted for visual acuity outcomes ≥20/63.

Conclusions—Cataract blindness control is well underway in rural China as evidenced by significant increases in cataract surgical coverage and improvement in visual acuity outcomes during the 2006–2014 interval. Further efforts are needed to provide greater access to affordable cataract surgery for the elderly, females and those with little or no education.

Graphical Abstract

Population-based surveys of adults 50 years of age or older were conducted in nine rural counties/districts in nine provinces of China. Cataract surgical coverage has increased significantly over recent years and with substantially improved visual acuity outcomes. Unoperated cataract is associated with older age, female gender, and lack of education.

Keywords

cataract; cataract surgical coverage; population-based survey; visual acuity

INTRODUCTION

As evidenced by the SightFirst China Action Program, initiated in 1997 by the State Council Coordination Committee on Disability and the Ministry of Public Health in partnership with Lions Clubs International, cataract blindness has been a high priority public health issue in China for over two decades. The first and second phases of the program (1997–2007) were focused on increasing cataract surgical coverage-- with a third phase (2010–2015) focused on the elimination of blinding trachoma. The government has also supported a mobile van for cataract surgery in 12 provinces in the west area of China since 2003; and more recently, under the “One Million Cataract Blindness Project” 1.65 million cataract surgeries were performed over the 2009–2013 period. Additionally, Universal Medical Insurance, launched in 2003 with joint funding by central and local governments, improved affordability of eye care in rural areas, achieving 95% coverage of the Chinese population by 2012.

Non-governmental organizations (NGOs), such as ORBIS International, the Fred Hollows Foundation, and the Chinese Ophthalmologic Society, have also been active in cataract

surgery projects in rural areas; with the number of cataract surgeries performed by the private sector increasing to the extent that it is now comparable to that in the public sector (unpublished data, National Cataract Surgery Registry Network).

In addressing the need for representative data in characterizing the magnitude and nature of vision impairment and blindness among rural populations in China, the National Health Ministry carried out a "China Nine-Province Survey" in 2006.[1–3] This survey was implemented in 9 rural districts and counties within the 4 municipalities, 22 provinces, and 5 autonomous regions of mainland China: 1 municipality (Beijing) and 2 provinces (Jiangsu and Guangdong) in the East Coast region; 3 provinces (Heilongjiang, Hebei and Jiangxi) in the inland Middle region; and 1 municipality (Chongqing), 1 province (Yunnan), and 1 autonomous region (Xinjiang) in the West region.

With continuing urbanization and lifestyle changes, along with increasingly modern medical care, the Chinese government recognized the need for an updated assessment of vision impairment and blindness among rural populations in China. Accordingly, a new Nine-Province Survey was launched in 2014 with administrative oversight by the National Institute of Hospital Administration and technical expertise provided by Peking Union Medical College (PUMC) Hospital. The importance of periodic assessments to monitor changes in the magnitude and causes of vision impairment over time, along with the effectiveness of eye-care services, has been emphasized in a WHO (World Health Organization) global health action plan.[4]

The new Nine-Province Survey was to be carried out in the same counties and districts as the earlier survey, and with the same study methods. However, because of the social situation in the Xinjiang successful implementation of the 2014 survey could not be guaranteed, and it was replaced with Tongxin county in the Ningxia Hui autonomous region in western China with similar sociodemographic characteristics including a large Muslim population. The total population in the nine rural counties/districts targeted in 2014 was 6,042,924, with approximately 27% aged ≥50 years.[5]

A previous article reported on the prevalence of visual impairment and blindness in each of the nine study provinces in the 2014 survey with comparisons from the earlier 2006 survey.[6] Here we present results from the 2014 survey on cataract surgical coverage among those visually impaired or blind from cataract, along with visual acuity outcomes in cataract operated eyes, with comparisons of data from 8 of the 9 provinces in the 2006 survey.

METHODS

The study design was a population-based, geographically-sampled, cross-sectional study of vision impairment and blindness and cataract surgery in previously studied rural sites with the same study protocol. Human subject research approval of the original study protocol and the scripted consent form for obtaining written informed consent was cleared by the WHO Secretariat Committee on Research Involving Human Subjects. The PUMC Hospital Committee on Ethics on Research approved implementation of the current study.

The selection and sampling of the study sites along with the survey and examination protocol adapted from the 2006 Nine-Province Survey were previously described.[1–3, 6] Examination methods are briefly summarized below.

Presenting distance visual acuity (PVA), with spectacles if the participant had them at presentation, was measured using a retro-illuminated logarithm of the minimum angle of resolution (LogMAR) “illiterate E” chart. Participants with PVA 20/40 or worse in either eye were refracted with subjective refraction to achieve best-corrected visual acuity (BCVA). Ophthalmic examination of the eyelid, globe, pupillary reflex, and lens was carried out by a study ophthalmologist. The type of cataract surgery, posterior capsule status, and signs of surgical complications were noted in the examination of cataract-operated eyes. Pupils of eyes with BCVA 20/40 or worse were dilated for direct ophthalmoscopy and slit lamp examination, followed by fundus photography if the media was clear.

At the time of the study examination, participants with PVA 20/40 or worse in the better-seeing eye correctable with refraction were provided with a prescription for spectacles. Treatment for minor ophthalmic problems was provided, free of charge. Those with PVA worse than 20/200 because of cataract were referred for surgery. Others requiring further management were given an explanation of the problem and referred to the hospital/clinic nearest their home.

Data Management and Analysis

The prevalence of cataract surgery in study participants (unilaterally- or bilaterally-operated) was calculated by age, sex, education, and study site.

The burden of cataract-related bilateral vision impairment and blindness was defined as comprising both operated and unoperated persons: (A) cataract-operated persons who were bilaterally impaired at the time of cataract surgery, and (B) unoperated persons with bilateral impairment caused by cataract in at least one eye. Without pre-operative visual acuity data, it was unknown whether cataract-operated persons were initially bilaterally visually impaired. Accordingly, it was *presumed* that both eyes were impaired at the time of the first cataract surgery in bilaterally operated persons, and for unilaterally operated persons, it was *presumed* that the cataract-operated eye was initially impaired with an impaired fellow eye.[3] The calculation of the cataract-related burden is specific to the visual acuity threshold used in defining vision impairment: it excludes unilaterally cataract-operated persons with visual acuity in the unoperated eye better than the threshold as well as unoperated persons with visual acuity better than the threshold in one or both eyes.

Cataract surgical coverage was calculated as the already-operated visually impaired and blind (group A) divided by the cataract-related burden (group A + group B). As with the burden of cataract-related vision impairment, the calculation of cataract surgical coverage is specific to the visual acuity threshold used in defining vision impairment. The emphasis was on investigating cataract surgical coverage for severe vision impairment and blindness (<20/200), treated as blindness in many developed countries, and for comparison purposes surgical coverage for blindness (<20/400) and surgical coverage when moderate vision impairment was included (<20/63). Multiple logistic regression odds ratios (OR) and *P*

values were used to quantify the association of age, sex, and education level with cataract surgical coverage within each study site. [Education level was obtained during the household enumeration of eligible study subjects using the following categorization: no education, less than primary education (≈4 years), primary education (≈ 8 years), and secondary education (≈12 years) or greater.

PVA and BCVA outcomes in cataract-operated eyes were categorized based on WHO recommendations: 20/32 or better (very good); 20/40 to 20/63 (good); worse than 20/63 to 20/200 (intermediate); and worse than 20/200 (poor).[7] Multiple logistic regression was used to investigate the association of age, sex and education level with presenting and best-corrected visual acuity ≥20/63 in cataract-operated eyes.

Cataract surgical coverage for cataract-related severe vision impairment or blindness (<20/200) in 2014 was compared to that in 2006. Change in surgical coverage over the 2006–2014 interval was expressed as a percentage of the 2006 coverage. “Effective” cataract surgical coverage, representing a downward adjustment of surgical coverage to include only cataract-operated persons with a good surgical outcome, was calculated using PVA in cataract-operated eyes.[8] In a unilaterally-operated person, a good surgical outcome was defined as PVA ≥20/63 in the cataract operated eye, with a bilaterally-operated person requiring PVA ≥20/63 in the better-seeing eye. Effective cataract surgical coverage in 2014 was compared to that in 2006.

Statistical analyses were performed using Stata/SE Data Analysis and Statistical Software: Release 12.0 (StataCorp, College Station, Texas, USA). Confidence intervals, odds ratios and *P* values (significant at the $P \leq 0.05$ level) were calculated with adjustment for clustering effects associated with the sampling design.

RESULTS

Prevalence of Cataract Surgery

Across all nine study sites, the 2014 survey population consisted of 51,310 examined participants ≥50 years of age. Overall 2,100 participants were operated on for cataract: 1,323 unilaterally and 777 bilaterally. As shown in Table 1, the prevalence of cataract surgery increased with age, was somewhat higher in females, and relatively high in those without formal education – reflective of rural areas where elderly residents have little or no education. The overall prevalence of cataract surgery was 4.09%, ranging from 1.58% in Heilongjiang to 6.37% in Guangdong.

In multiple logistic regression modeling with age category, sex, education category, and study sites as covariates, cataract surgery was associated with older age (50–59: reference; 60–69: OR:2.96, P<0.001; 70–79: OR:8.35, P<0.001; 80+: OR:16.2, P<0.001), female sex (OR:1.21, P<0.001), and lack of formal education (None: reference; < Primary: OR:0.82, P=0.008; Primary: OR:0.92, P=.324; Secondary: OR:0.92, P=0.397). Compared to Beijing (used as the regression reference to maintain consistency with previous 2006 and 2014 survey publications[3, 6]), the prevalence of cataract surgery was low in Jiangsu (OR:0.65,

P<0.001), Heilongjiang (OR:0.43, P<0.001), and Ningxia (OR:0.44, P<0.001). A relatively high prevalence in Guangdong was not statistically significant (OR:1.10, P=0.435).

Cataract Burden

Among the 2,100 cataract-operated persons, 1,250 were presumed to have had bilateral severe vision impairment or blindness (<20/200) at the time of surgery. Additionally, 743 with un-operated cataract in one or both eyes were bilaterally severely impaired or blind (Table 1). Accordingly, the burden of cataract-related severe vision impairment or blindness affected 1,993 (3.88%) of the study participants, ranging from 1.65% in Ningxia and 1.78% in Heilongjiang to 6.49% in Guangdong and 7.80% in Yunnan.

In multiple logistic regression modeling, cataract-related severe vision impairment and blindness was associated with older age (50–59: reference; 60–69: OR:3.32, P<0.001; 70–79: OR:12.7, P<0.001; 80+: OR:41.0, P<0.001), female sex (OR:1.37, P<0.001), lack of formal education (None: reference; < Primary: OR:0.79, P=0.003; Primary: OR:0.84, P=.029; Secondary: OR:0.69, P=<0.001), and compared to Beijing was low in Jiangsu (OR: 0.69, P=0.008), Heilongjiang (OR:0.72, P=0.010) and Ningxia (OR:0.55, P=0.001), and high in Guangdong (OR:1.27, P=0.050) and Yunnan (OR:1.63, P<0.001).

Cataract Surgical Coverage

As shown in Table 1, cataract surgical coverage was 62.7% overall among the operated and unoperated with cataract-related severe vision impairment and blindness (<20/200). Surgical coverage decreased from 71.8% to 53.8% in the 50–59 to 80+ age groups, was 65.7% in males versus 60.9% in females, and increased from 57.0% to 82.7% as education levels increased. Surgical coverage ranged from 43.4% in Yunnan to 83.6% in Beijing.

Table 2 shows surgical coverage for cataract-related moderate vision impairment or worse (<20/63), severe vision impairment or worse (<20/200) and blindness (<20/400). Across all study sites, surgical coverage for moderate vision impairment or worse was 30.6% (95% CI: 28.8%–32.4%), increasing to 62.7% (95% CI: 59.7%–65.8%) for severe vision impairment and blindness, and increasing further to 71.7% (95% CI: 68.5%–74.9%) for blindness. The substantial decrease in surgical coverage when the threshold for cataract-related vision impairment/blindness was increased from <20/200 to <20/63 is driven by the rising number of un-operated cataract, while the number of cataract-operated doesn't expand at a similar rate: those with un-operated cataract increases from 743 (1.45%) to 3,372 (6.96%), while the already cataract-operated increases from 1,250 (2.44%) to 1,573 (3.07%). The result is a cataract burden that increases from 1,993 (3.88%) to 5,145 (10.0%), and a surgical coverage that decreases from 62.7% (1,250/1,993) to 30.6% (1,573/5,145).

As shown in the Table 2, surgical coverage generally decreased with increasing age for all 3 thresholds for cataract-related vision impairment or blindness (<20/63, <20/200, and <20/400), as was statistically significant in Yunnan; in Jiangsu and Chongqing surgical coverage increased with increasing age at a statistically significant level <20/63. Surgical coverage was generally increased with increasing education, and at notably significant levels in Ningxia and Chongqing. Sex was not a significant factor in any of the study sites.

When study site was included as a covariate in multiple logistic regression modeling with all sites combined, and Beijing as the regression reference, surgical coverage was significantly lower for <20/63, <20/200 and <20/400 thresholds of vision impairment/blindness in Jiangsu (respective odds ratios with *P* values: 0.56, <0.001; 0.31, <0.001; 0.36, 0.003), Heilongjiang (0.34, <0.001; 0.29, 0.001, 0.26, 0.001) , Ningxia (0.63, 0.050; 0.39, 0.013; 0.43, 0.021), and Yunnan(0.51, <0.001; 0.21, 0.001; 0.18, <0.001); significantly lower for <20/63 and <20/200 in Guangdong (0.62, 0.008; 0.48, 0.026; 0.84, 0.658); and significantly lower for <20/63 in Hebei (0.61, 0.011; 0.54, 0.069; 0.75, 0.441).

Visual Acuity Outcomes

The distribution of PVA for the 2,877 cataract-operated eyes in the 2,100 cataract-operated persons in 2014 is shown in Table 3. Based on multiple logistic regression modeling, PVA ≥20/63 (a good visual acuity outcome) in cataract-operated eyes overall was significantly less frequent in females compared to males, and more frequent in those with at least some level of education; age was not significant. Within study sites, good visual acuity outcomes were less frequent among those 80+ years of age in Hebei and among those 70 years or older in Yunnan, but more frequent among those 70 years or older in Chongqing. Education level was significant in Hebei and Chongqing.

With study site included as a covariate in the multiple regression modeling and Beijing as the reference site, PVA ≥20/63 was significantly more frequent in Chongqing (OR: 1.61; P=0.020), but significantly less frequent in Jiangxi (OR: 0.49; P<0.001). Good outcomes were also less frequent in Heilongjiang, Hebei, Ningxia, and Yunnan, but not at statistically significant levels.

The distribution of BCVA for cataract-operated eyes is shown in Table 4. Overall, BCVA ≥20/63 was more frequent among those with some education. Sex and age were not significant. Within study sites, good outcomes were more frequent in those older than 50–59 years in Jiangxi, Ningxia, and Chongqing, generally at statistically significant levels. Good outcomes were statistically more frequent among those with at least primary education in Chongqing.

With study site was included as a covariate in the multiple regression modeling and Beijing as the reference site, BCVA ≥20/63 was significantly more frequent in Chongqing (OR: 1.54; P=0.043), but significantly less frequent in Heilongjiang (OR: 0.46; P=0.002), Jiangxi (OR: 0.51; P=0.001), Ningxia (OR: 0.64; P=0.045), and Yunnan (OR: 0.50; P=0.001).

The influence of the interval between the time of cataract surgery and the year of the survey on vision impairment was investigated by including the time interval length as a covariate in multiple logistic regression modeling. An increased time interval was associated with visual acuity <20/63 in all study sites, and at statistical significant levels (P ≤0.05) in Guangdong, Jiangxi, Hebei, Ningxia, and Chongqing for PVA and in Guangdong, Jiangxi, Hebei, Ningxia, and Yunnan for BCVA.

Comparisons of 2006 and 2014 Survey Data

Table 5 shows a 2006–2014 comparison of surgical coverage for cataract-related severe vision impairment or blindness (<20/200), along with the percentage of cataract-operated persons with PVA ≥20/63 in one or both cataract-operated eyes. The PVA ≥20/63 percentage for 2014 survey data in Table 5 is uniformly greater than the percentage with PVA ≥20/63 in Table 3: Table 5 deals with PVA outcomes in cataract-operated persons with cataract-related severe vision impairment or blindness – based on the cataract-operated eye in unilaterally operated persons and in the better-seeing operated eye in the bilaterally operated – whereas Table 3 deals with all cataract-operated eyes.

Cataract surgical coverage in 2014 compared to 2006 increased by a minimum of +34.3% to a maximum of 153%. The percentage of cataract-operated persons with PVA ≥20/63 (a good visual acuity outcome) in one or both cataract-operated eyes increased over the 2006–2014 interval, except in Yunnan where it decreased from an exceptionally high 81.0% to a more typical 62.4%. Accordingly, other than Yunnan, the percentage increase in effective surgical coverage was greater than the unadjusted surgical coverage, increasing from a minimum of +52.8% to a maximum of +328%; in Yunnan effective surgical coverage was 27.2% compared to an unadjusted 78.2%. The percentage increases in surgical coverage over the 2006–2014 interval were statistically significant at the $P<0.001$ level (equality of proportions test), except for the modest 27.2% increase in effective surgical coverage in Yunnan significant at the $P<=0.033$ level.

DISCUSSION

The strengths of the 2014 Nine-Province Survey were a large, randomly selected, population-based sample of rural participants in nine counties/districts throughout mainland China, use of the same study protocol at each study site, and examination response rates that exceeded 85% at each site. Random selection of the study samples allowed for calculation of confidence intervals around parameter estimates, standardized measurement methods and definitions ensured that inter-site data comparisons were valid, and high examination response rates minimized the effect of self-selection bias. Study sites were previously surveyed in 2006 (except for Ningxia) using the same protocol and examination methods, which allowed for direct comparisons of changes in cataract surgery coverage and visual acuity in cataract-operated persons over the 2006–2014 interval.

Overall, cataract surgery increased with increasing age, was more prevalent in females and in those with no education. However, because of a disproportionately high burden of cataract-related vision impairment and blindness, cataract surgical coverage rates decreased with increasing age and with lower levels of education. Good visual acuity outcomes in cataract-operated eyes were significantly less frequent in females and in those without education; although there was a lower frequency of good outcomes in those aged 80+, it was not statistically significant.

In comparison with 2006 survey results, surgical coverage for cataract-related severe vision impairment and blindness increased significantly within all study sites. The increases in Heilongjiang, Jiangxi, and Chongqing were particularly dramatic, where low surgical

coverage in 2006 more than doubled by 2014. With this increase in cataract surgical coverage coupled with an increase in good visual acuity outcomes, the increase in effective surgical coverage was even more pronounced by more than tripling. The percent change in surgical coverage and effective surgical coverage was remarkably inversely correlated with the 2006 levels: those with the lowest coverage in 2006 experienced the greatest increase in coverage by 2014. The exception was Yunnan where an unusually high percentage of cataract-operated eyes with good visual acuity in 2006 dropped to more typical levels in 2014, resulting in an improvement of effective surgical coverage that was less than the improvement in surgical coverage without the visual acuity adjustment. The atypical visual acuity outcomes in Yunnan in 2006 were associated with an NGO-sponsored cataract surgery initiative where priority was given to cases with a high likelihood of full vision restoration -- those *without* dense lens opacities and a media and fundus examination adequate to rule out any co-existing abnormalities.[3]

The substantial drop in surgical coverage rates when the threshold for cataract-related vision impairment and blindness was <20/63, compared to <20/200, is an indication that many of those with bilateral vision impairment in the <20/63 to 20/200 range are going un-operated. In contrast, when the threshold was set at <20/400 (dealing only with blindness), the increase in surgical coverage was comparatively small; an indication that the current demand for cataract surgery includes those with vision impairment between <20/200 and 20/400. As the demand for earlier cataract surgery increases, the difference in surgical coverage between the <20/63 and <20/200 thresholds will eventually narrow. It is hypothesized that surgical coverage suffers, in part, from an attitude that good vision is not a necessity in daily life, which is expected to change as rural populations experience lifestyle changes and take on tasks with greater requirements for better vision.

It should be recognized that because of the presumption that all cataract-operated eyes had been visually impaired or blind the calculation of surgical coverage produces an overestimate of actual coverage. Without knowing pre-operative visual acuity, it was necessary to make such assumptions regarding visual acuity at the time of cataract surgery. The error decreases (increases) as the visual acuity threshold used in defining visual impairment or blindness is increased (decreased). Accordingly, with a moderate vision impairment threshold (<20/63), the overstatement of surgical coverage is likely to be relatively minor.

Even after adjustment for sex, age and education with multiple logistic regression modeling, significant site-specific differences in the magnitude of cataract burden and surgical coverage remain: For example, the cataract-related burden was high in Yunnan, with low cataract surgical, and also high in Guangdong, but with typical surgical coverage. Cataract burden in Heilongjiang and Ningxia were relatively low, and surgical coverage was also low because of the low prevalence of cataract surgery. It is recognized that a variety of site-specific cultural, socioeconomic and service-delivery factors underlie these differences. The survey was deficient in that no attempt was made to solicit reasons for not seeking surgery among those with vision impairment because of unoperated cataract. Future study is needed to better understand issues related to awareness, attitudes, access, and affordability in influencing cataract surgery uptake, particularly among the elderly and the illiterate. Such

information would be helpful in the formulation of strategies to improve the effectiveness of eye-health education and other prevention of blindness efforts.

A limitation of study data is that visual acuity measured at the time of the survey is an underrepresentation of the effectiveness of cataract surgery in sight restoration. The onset of post-surgical ocular co-morbidities during the time interval between cataract surgery and the subsequent survey examination, such as age-related macular degeneration and diabetic retinopathy, have the potential to adversely affect visual acuity. A lengthening of the time interval, which was commonly 3–4 years, was significantly associated with decreased visual acuity.

It would be helpful if pre-operative visual acuity was included in the National Cataract Surgery Registry Network to allow for a more accurate characterization of the uptake of cataract surgery. Similarly, post-surgical visual acuity would be useful in more accurately evaluating the sight restoring benefits of cataract surgery. This survey has been able to provide a reasonably accurate characterization of those not receiving cataract surgery, but is lacking with regard to those who have already received cataract surgery.

Surgical coverage among those presenting with cataract-related severe visual impairment or blindness (<20/200) ranged from 43.4% to 83.6%, which is an overall increase in surgical coverage by 81.4% from 2006 to 2014. This represents major progress in cataract blindness control undertaken by the SightFirst China Action Program in collaboration with other major national, international and NGO efforts, and a major contributing factor in the significant reduction in the prevalence of vision impairment and blindness over the 2006–14 interval.[6]

Survey findings underscore the continuing need to pursue high quality cataract surgery outcomes, including careful case screening and periodic post-surgical follow-up. Differences between PVA and BCVA highlight the issue of uncorrected refractive error in cataract-operated eyes. The need for refractive correction would be minimized if increased attention was given to accurate biometric measurements in the determination of appropriate IOL power. Although refractive error is easily treated with spectacles, patients may not be receiving the necessary correction for a number of reasons, including a perception that sharp vision is not needed, the lack of a postoperative follow-up examination, and the cost of spectacles. This remains an important area for future study.

In summary, cataract blindness control in rural China is now well underway, but further efforts are needed to increase coverage in the elderly, females and the less educated. Efforts to provide access to affordable cataract surgery among those with only *moderate* cataract-related vision impairment with an emphasis on good visual acuity outcomes will be of increased importance as China continues its rapid pace of economic development.

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TABLE 1

The prevalence of cataract surgery and cataract surgical coverage among those with severe vision impairment or blindness (VA<20/200) because of cataract in one or both eyes by age, sex, education level, and study site in the 2014 survey.

Study Variable	Examined		Cataract-Operated Persons				Un-Operated Cataract VI/BL Persons [b]		Cataract Surgical Coverage (%)
			Total Operated		Presumed VI/BL[a]				
	No.	(%)	No.	Prevalence (%)	No.	Prevalence (%)	No.	Prevalence (%)	
Age (y)									
50–59	18,224	(35.5)	182	1.00	74	0.41	29	0.16	71.8
60–69	19,435	(37.9)	545	2.80	258	1.33	109	0.56	70.3
70–79	10,218	(19.9)	830	8.12	505	4.94	250	2.45	66.9
80+	3,433	(6.69)	543	15.8	413	12.0	355	10.3	53.8
Sex									
Male	22,245	(43.4)	850	3.82	495	2.23	259	1.16	65.7
Female	29,065	(56.7)	1,250	4.30	755	2.60	484	1.67	60.9
Education Level									
None	17,423	(34.0)	1,088	6.24	695	3.99	525	3.01	57.0
Less than Primary	9,838	(19.2)	348	3.54	204	2.07	102	1.04	66.7
Primary	12,586	(24.5)	375	2.98	212	1.68	87	0.69	70.9
Secondary or More	11,463	(22.3)	289	2.52	139	1.22	29	0.25	82.7
Study Site									
Beijing	5,310	(10.4)	208	3.92	117	2.20	23	0.43	83.6
Jiangsu	5,823	(11.4)	219	3.76	112	1.92	83	1.43	57.4
Guangdong	5,638	(11.0)	359	6.37	232	4.11	134	2.38	63.4

Study Variable	Examined		Cataract-Operated Persons				Un-Operated Cataract VI/BL Persons [b]		Cataract Surgical Coverage (%)
			Total Operated		Presumed VI/BL[a]				
	No.	(%)	No.	Prevalence (%)	No.	Prevalence (%)	No.	Prevalence (%)	
Heilongjiang	5,381	(10.5)	85	1.58	57	1.06	39	0.72	59.4
Jiangxi	5,511	(10.7)	245	4.45	159	2.89	45	0.82	77.9
Heibei	6,282	(12.2)	224	3.57	119	1.89	49	0.78	70.8
Ningxia	4,982	(9.71)	90	1.81	53	1.06	29	0.58	64.6
Chongqing	6,791	(13.2)	342	5.04	212	3.12	94	1.38	69.3
Yunnan	5,592	(10.9)	328	5.87	189	3.38	247	4.42	43.4
All Study Sites	51,310	(100.0)	2,100	4.09	1,250	2.44	743	1.45	62.7

[a] Bilaterally-operated and presumed to have been visually impaired or blind (visual acuity < 20/200) in both eyes because of cataract or unilaterally operated and presumed to have been visually impaired or blind in both eyes with cataract in one or both eyes.

[b] Visually impaired or blind (visual acuity < 20/200) in both eyes with unoperated cataract in at least one eye.

TABLE 2

Odds ratios in multiple logistic regression modeling of surgical coverage for cataract-related moderate vision impairment or worse (< 20/63), severe vision impairment or worse (< 20/200) and blindness (< 20/400) within the 2014 study sites. Age in years and education level were modeled as continuous variables.

Study Site	Surgical Coverage Percentage (95%Confidence Interval)	Odds Ratio (*P* Value) [a]		
		Female Sex	Age (years)	Education (level)
Beijing				
<20/63	48.2 (42.1–54.3)	1.13 (0.670)	0.99 (0.522)	1.19 (0.326)
<20/200	83.6 (76.3–90.8)	0.79 (0.651)	0.97 (0.404)	1.10 (0.713)
<20/400	88.1 (82.4–93.8)	0.94 (0.921)	0.95 (0.374)	1.10 (0.775)
Jiangsu				
<20/63	29.7 (26.3–33.0)	0.90 (0.695)	0.96 (0.002) **	1.22 (0.088)
<20/200	57.4 (51.3–63.6)	0.86 (0.716)	0.98 (0.216)	1.10 (0.713)
<20/400	68.5 (62.3–74.6)	1.20 (0.720)	0.95 (0.074)	1.22 (0.499)
Guangdong				
<20/63	29.7 (25.6–33.0)	1.13 (0.392)	0.99 (0.280)	1.03 (0.755)
<20/200	63.4 (56.6–70.2)	0.64 (0.078)	0.98 (0.080)	0.97 (0.852)
<20/400	80.3 (73.3–87.3)	0.48 (0.112)	0.98 (0.172)	0.87 (0.478)
Heilongjiang				
<20/63	22.9 (17.8–27.9)	0.84 (0.562)	0.99 (0.731)	0.97 (0.824)
<20/200	59.4 (50.2–68.6)	0.72 (0.491)	1.00 (0.971)	0.96 (0.892)
<20/400	66.3 (56.4–76.1)	0.62 (0.372)	1.01 (0.689)	0.96 (0.903)
Jiangxi				
<20/63	33.8 (29.7–37.8)	0.86 (0.467)	0.98 (0.256)	1.21 (0.101)
<20/200	77.9 (70.8–85.1)	0.56 (0.230)	0.96 (0.150)	1.09 (0.715)
<20/400	89.7 (83.8–95.6)	0.38 (0.233)	0.96 (0.413)	1.28 (0.488)
Hebei				
<20/63	31.5 (25.8–37.2)	0.97 (0.900)	0.98 (0.080)	1.23 (0.045) *
<20/200	70.8 (63.6–78.1)	0.68 (0.342)	0.95 (0.055)	1.07 (0.641)
<20/400	83.3 (76.6–89.8)	0.71 (0.526)	1.00 (0.950)	1.15 (0.538)

Study Site	Surgical Coverage Percentage (95%Confidence Interval)	Odds Ratio (*P* Value) [a]		
		Female Sex	Age (years)	Education (level)
Ningxia				
<20/63	31.3 (23.9–38.8)	1.47 (0.229)	0.99 (0.576)	1.49 (0.011) *
<20/200	64.6 (55.0–74.3)	1.07 (0.893)	1.00 (0.901)	1.76 (0.047) *
<20/400	73.5 (65.3–81.8)	1.19 (0.791)	1.00 (0.937)	2.29 (0.127)
Chongqing				
<20/63	32.0 (24.2–39.8)	1.10 (0.636)	1.04 (0.001) **	1.37 (0.034) *
<20/200	69.3 (61.0–77.6)	0.93 (0.792)	1.01 (0.711)	1.53 (0.011) *
<20/400	75.2 (67.3–83.1)	0.85 (0.564)	0.99 (0.451)	1.43 (0.048) *
Yunnan				
<20/63	25.1 (22.8–27.4)	1.05 (0.713)	0.95 (0.002) **	0.89 (0.583)
<20/200	43.3 (38.2–48.5)	0.99 (0.962)	0.92 (0.004) **	1.33 (0.032) *
<20/400	48.0 (41.8–54.2)	0.93 (0.744)	0.91 (0.002) **	1.51 (0.551)
All Study Sites				
<20/63	30.6 (28.8–32.4)	1.05 (0.517)	0.99 (0.012) *	1.23 (<0.001) **
<20/200	62.7 (59.7–65.8)	0.90 (0.334)	0.97 (<0.001) **	1.31 (<0.001) **
<20/400	71.7 (68.5–74.9)	0.96 (0.750)	0.96 (<0.001) **	1.39 (<0.001) **

[a] Statistical significance at the $P \leq 0.050$ level is indicated by 1 asterisk (*) and significance at the $P \leq 0.010$ level by 2 asterisks (**).

TABLE 3

Presenting visual acuity of cataract-operated eyes and odds ratios in multiple logistic regression modeling of visual acuity ≥20/63 with sex, age, and education level within the 2014 study sites.

Study Site	Operated Eyes	Presenting Visual Acuity				Odds Ratio (*P* Value) [a]						
		≥20/32	20/40–20/63	<20/63–20/200	<20/200	Female Sex	Age Category (Reference: 50–59)			Education Level (Reference: None)		
							60–69	70–79	80+	< Primary	Primary	Secondary
Beijing	298	30.2	37.9	17.5	14.4	0.98 (0.960)	1.41 (0.499)	1.24 (0.644)	0.98 (0.978)	0.68 (0.688)	0.54 (0.267)	0.78 (0.634)
Jiangsu	281	38.1	28.8	19.9	13.2	1.01 (0.974)	1.03 (0.948)	1.26 (0.713)	0.60 (0.417)	1.64 (0.262)	2.63 (0.062)	0.70 (0.403)
Guangdong	504	18.7	42.9	18.7	19.8	0.98 (0.933)	0.72 (0.500)	0.92 (0.856)	0.50 (0.074)	0.86 (0.505)	0.52 (0.331)	0.93 (0.797)
Heilongjiang	112	34.8	25.0	17.0	23.2	0.74 (0.484)	1.49 (0.550)	1.20 (0.727)	0.44 (0.362)	1.07 (0.484)	1.09 (0.891)	3.40 (0.229)
Jiangxi	341	18.2	29.0	28.2	24.6	0.68 (0.163)	3.54 (0.051)	1.55 (0.470)	1.01 (0.983)	0.65 (0.176)	0.80 (0.667)	0.40 (0.185)
Hebei	297	33.0	28.0	21.2	17.9	0.70 (0.135)	0.54 (0.318)	0.62 (0.425)	0.30 (0.037)*	2.58 (0.064)	1.86 (0,043)*	0.96 (0.898)
Ningxia	122	25.4	32.8	20.5	21.3	0.76 (0.537)	0.92 (0.873)	1.44 (0.403)	0.73 (0.684)	1.16 (0.806)	0.96 (0.951)	1.72 (0.357)
Chongqing	494	43.1	31.2	16.6	9.11	0.79 (0.389)	2.63 (0.118)	4.00 (0.019)*	6.98 (0.002)*	1.07 (0.804)	2.67 (0.015)*	3.57 (0.007)*
Yunnan	428	46.0	10.5	24.5	19.0	0.82 (0.330)	0.67 (0.367)	0.35 (0.023)*	0.35 (0.083)	0.92 (0.850)	0.54 (0.326)	No data
All Sites	2,877	32.4	29.9	20.6	17.2	0.83 (0.006) **	1.06 (0.777)	1.06 (0.760)	0.85 (0.436)	1.18 (0.125)	1.33 (0.027)*	1.33 (0.054)

[a] Statistical significance at the $P \leq 0.050$ level is indicated by an asterisk (*). .

TABLE 4

Best-corrected visual acuity of cataract-operated eyes and odds ratios in multiple logistic regression modeling of visual acuity ≥20/63 with sex, age, and education level within the 2014 study sites.

Study Site	Operated Eyes	Best Corrected Visual Acuity				Odds Ratio (*P* Value) [a]						
		≥20/32	20/40–20/63	<20/63–20/200	<20/200	Female Sex	Age Category (Reference: 50–59)			Education Level (Reference: None)		
							60–69	70–79	80+	< Primary	Primary	Secondary
Beijing	298	56.0	25.5	7.72	10.7	1.23 (0.651)	0.82 (0.797)	0.57 (0.475)	0.41 (0.310)	0.59 (0.616)	0.70 (0.572)	0.88 (0.819)
Jiangsu	281	53.0	22.8	12.8	11.4	1.31 (0.409)	0.61 (0.351)	0.99 (0.993)	0.30 (0.163)	1.72 (0.205)	2.15 (0.152)	0.49 (0.102)
Guangdong	504	44.8	31.0	9.52	14.7	1.07 (0.726)	0.61 (0.308)	1.19 (0.743)	0.58 (0.270)	1.01 (0.970)	0.71 (0.397)	0.66 (0.207)
Heilongjiang	112	50.9	17.9	11.6	19.6	0.69 (0.407)	1.52 (0.599)	1.44 (0.595)	0.58 (0.524)	0.90 (0.900)	1.90 (0.287)	3.14 (0.271)
Jiangxi	341	42.2	24.9	14.7	18.2	0.87 (0.659)	3.31 (0.041)*	2.385 (0.073)	1.56 (0.374)	0.83 (0.565)	0.94 (0.903)	0.93 (0.909)
Hebei	297	56.6	18.2	10.4	14.8	0.56 (0.069)	0.86 (0.832)	0.92 (0.912)	0.44 (0.209)	3.40 (0.080)	1.58 (0.304)	0.62 (0.274)
Ningxia	122	55.7	17.2	9.84	17.2	0.80 (0.676)	1.72 (0.366)	2.69 (0.027)*	3.67 (0.115)	3.95 (0.120)	1.20 (0.741)	1.59 (0.536)
Chongqing	494	67.2	18.2	9.51	5.06	1.00 (0.997)	3.57 (0.026)*	4.08 (0.013)*	6.42 (0.006)*	1.01 (0.968)	4.79 (0.005)*	2.62 (0.105)
Yunnan	428	61.2	5.84	17.8	15.2	0.65 (0.075)	0.67 (0.361)	0.39 (0.070)	0.29 (0.072)	0.89 (0.782)	0.60 (0.324)	No data
All Sites	2,877	54.7	20.5	11.7	13.1	0.89 (0.265)	1.12 (0.563)	1.25 (0.262)	0.90 (0.641)	1.25 (0.073)	1.43 (0.007)*	1.23 (0.182)

[a] Statistical significance at the $P \leq 0.050$ level is indicated by an asterisk (*).

TABLE 5

Surgical coverage for cataract-related severe vision impairment or blindness (< 20/200) and the percentage with presenting visual acuity ≥20/63 in one or both cataract-operated eyes in the 2006 and 2014 surveys.

Study Site	2006 Survey			2014 Survey			2006–2014 Change [a]	
	Surgical Coverage (%)	Presenting VA ≥20/63 (%)	Effective Surgical Coverage (%) [b]	Surgical Coverage (%)	Presenting VA ≥20/63 (%)	Effective Surgical Coverage (%) [b]	Change in Surgical Coverage	Change in Effective Surgical Coverage
Beijing	62.2	69.1	43.0	83.6	78.6	65.7	+34.3%	+52.8%
Jiangsu	38.0	51.2	19.4	57.4	68.8	39.5	+51.1%	+103%
Guangdong	45.5	48.2	21.9	63.4	69.0	43.7	+39.3%	+99.5%
Heilongjiang	24.4	37.5	9.16	59.4	63.2	37.5	+143%	+309%
Jiangxi	32.3	29.0	9.38	77.9	51.6	40.2	+141%	+328%
Heibei	41.1	56.9	23.4	70.8	67.2	47.6	+72.3%	+103%
Chongqing	27.4	54.2	14.8	69.3	78.3	54.3	+153%	+267%
Yunnan	26.3	81.0	21.3	43.3	62.4	27.1	+78.2%	+27.2%
All Study Sites	34.5	58.4	20.2	62.6	67.8	42.4	+81.4%	+110%

[a] Change in cataract surgical coverage was calculated as a proportional percentage of the 2006 surgical coverage. *P* values for differences in surgical coverage over the 2006–2014 interval were determined by tests on equality of proportions; changes were significant at the $P<0.001$ level except P =0.033 for the change in effective surgical coverage for Yunnan.

[b] Effective surgical coverage is a downward adjustment of surgical coverage to represent only cataract operated persons with a good surgical outcome (≥20/63) in cataract-operated eyes, which corresponds with multiplying the surgical coverage percentage by the presenting visual acuity ≥20/63 percentage.