

# Causes and Five-Year Incidence of Blindness and Visual Impairment in Urban Southern China: The Liwan Eye Study

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**PURPOSE.** We determined the causes and five-year incidence of blindness and visual impairment (VI) in an adult, urban Chinese population.

**METHODS.** Participants underwent a comprehensive eye examination at baseline in 2003 and then five years later. The World Health Organization (WHO) and United States (US) definitions were used to define incident blindness (WHO visual acuity [VA] < 20/400 in the better-seeing eye, US VA ≤ 20/200) and incident VI (WHO VA < 20/60–20/400, US VA < 20/40–>20/200).

**RESULTS.** Among 1405 baseline participants, 924 (75%) of 1232 survivors (87.7%) participated in the 5-year follow-up. The incidences of VI and blindness were 5.38% (95% confidence interval [CI] 3.99% ~ 7.07%) and 0.33% (95% CI 0.07% ~ 0.95%), respectively, based on the WHO definition, and 9.85% (95% CI 7.96% ~ 12.0%) and 1.42% (95% CI 0.76% ~ 2.41%), respectively, based on the US definition. Incidence of blindness and VI (WHO definition) increased significantly with older age ( $P < 0.001$ ) and poorer baseline presenting VA in the worse-seeing eye ( $P < 0.001$ ). The leading cause of best-corrected VI (WHO definition) was cataract (64.6%), whereas the main causes of presenting VI were refractive error (40.4%) and cataract (38.4%).

**CONCLUSIONS.** The incidence of VI in urban Southern China is high. The major causes are unoperated cataract and undercorrected refractive error, reflecting the need for better surgical and refractive care, even in this urban setting.

**Keywords:** visual impairment and blindness, incidence, causes, urban, China

Among the 39.4 million blind people worldwide, an estimated 8.2 million (20.9%) are living in China.<sup>1</sup> The backlog of blindness and visual impairment (VI) is expected to increase with the aging of the population. Data from the National Bureau of Statistics of China indicate that the proportion of persons aged 60 years and older will rise from 13.3% in 2010 to 34% in 2050.<sup>2</sup> In response to this and other major health challenges, China has made significant progress in improving its health care coverage, especially in urban areas. Notably, the establishment of the basic social medical insurance system (BSMIS) in urban areas in 1998 has resulted in a national insurance coverage rate of over 95% among urban dwellers.<sup>3–6</sup> However, little information is available about the incidence and causes of blindness and VI in urban China in recent years.<sup>7</sup> Such information has important public health implication for the allocation of eye care resources and policy-making in China, where the urban population (691 million or 51.3% of the total) recently has surpassed the number of rural dwellers.<sup>8</sup>

We performed a 5-year longitudinal, population-based study in Liwan, an urban neighborhood of Guangzhou, to describe the incidence and causes of blindness and VI in urban Southern China.

## METHODS

### Study Population

Details of the Liwan Eye Study have been described previously.<sup>9</sup> In brief, this was a population-based study initiated in 2003, with a follow-up in 2009 using the same protocol. At baseline, 75.4% (1405 of 1864) of eligible subjects (persons aged 50 years and over chosen by random cluster sampling among those resident for ≥6 months in Liwan District, Guangzhou) completed eye examinations and questionnaires. All participants in the baseline study were invited to take part in the follow-up examination. Presenting visual acuity (PVA), uncorrected visual acuity, and best-corrected visual acuity (BCVA) were recorded separately for each eye of all subjects. PVA was measured with an Early Treatment Diabetic Retinopathy Study (ETDRS) visual chart using habitually-worn refractive correction. Examination of the anterior and posterior segments was done using a slit-lamp (Topcon SL-8Z; Topcon, Inc., Tokyo, Japan) and +78 diopter (D) lens at ×16 magnification by an experienced ophthalmologist (Mingguang He) before and after dilation of the pupil. When the PVA was <20/40 in either eye, the BCVA was determined by subjective refraction without cycloplegia. For eyes with PVA < 20/40, the main causes of

TABLE 1. Age-Specific Incidence of VI and Blindness, Using the VI and Blindness Definitions of the US and WHO

Age Group, y	Visual Impairment				Blindness			
	BCVA		PVA		BCVA		PVA	
	N*	% (95% CI)	N*	% (95% CI)	N*	% (95% CI)	N*	% (95% CI)
World Health Organization†								
50-59	2/360	0.56 (0.07, 1.99)	14/342	4.09 (2.26, 6.77)	0/360	0 (0.00, 1.02)	0/360	0 (0.00, 1.02)
60-69	15/288	5.21 (2.94, 8.44)	34/260	13.1 (9.23, 17.8)	1/294	0.34 (0.01, 1.88)	1/294	0.34 (0.01, 1.88)
+70	31/244	12.7 (8.80, 17.5)	51/197	25.9 (19.9, 32.6)	2/263	0.76 (0.09, 2.72)	2/263	0.76 (0.09, 2.72)
Total	48/892	5.38 (3.99, 7.07)	99/799	12.4 (10.2, 14.9)	3/917	0.33 (0.07, 0.95)	3/917	0.33 (0.07, 0.95)
United States‡								
50-59	9/359	2.51 (1.15, 4.71)	26/332	7.83 (5.18, 11.3)	0/360	0 (0.00, 1.02)	1/357	0.28 (0.01, 1.56)
60-69	17/282	6.03 (3.55, 9.48)	56/249	22.5 (17.5, 28.2)	5/293	1.71 (0.56, 3.94)	7/288	2.43 (0.98, 4.94)
+70	60/232	25.9 (20.47, 32.0)	74/178	41.6 (34.2, 49.2)	8/263	3.04 (1.32, 5.91)	8/257	3.11 (1.35, 6.04)
Total	86/873	9.85 (7.96, 12.0)	156/759	20.6 (17.7, 23.6)	13/916	1.42 (0.76, 2.41)	16/902	1.77 (1.02, 2.86)

\* Number of incident cases/number of persons at risk (persons at risk were defined as those without the condition or with a less severe condition at baseline).

† Incident VI was defined as VA decreased to <20/60 to  $\geq$ 20/400 in the better-seeing eye at follow-up. Blindness was defined as VA decreased to <20/400 in the better-seeing eye at follow-up.

‡ Incident VI was defined as VA decreased to <20/40 to  $>$ 20/200 in the better-seeing eye at follow-up. Blindness was defined as VA decreased to  $\leq$ 20/200 in the better-seeing eye at follow-up.

blindness or VI were determined using a 16-item diagnostic checklist according to the definitions in the study protocol (Supplementary Table S1). A questionnaire was used to obtain information about patients' income, education, insurance status, and smoking history. Ethical approval was obtained from the Zhongshan University Ethics Review Board and the Research Governance Committee of Moorfields Eye Hospital in London, England. The study was conducted in accordance with the tenets of the World Medical Association's Declaration of Helsinki. Written informed consent was obtained from all subjects.

### Incident Visual Impairment and Blindness

Using the World Health Organization (WHO) definition, incident best-corrected VI was defined as BCVA  $\geq$  20/60 in both eyes at baseline, which decreased to <20/60 to 20/400 in the better-seeing eye at follow-up; incident blindness was defined as BCVA  $\geq$  20/400 in both eyes at baseline, which decreased to <20/400 in the better-seeing eye at follow-up. Incident VI and blindness were defined according to the United States (US) Standard in the same fashion, except that the cutoff for VI was <20/40 and for blindness it was  $\leq$ 20/200. We believe that this latter set of definition better reflects the fact that the visual demands of modern urban life, such as driving an automobile and viewing a screen, require higher levels of vision and, hence, a broader definition of vision impairment. The same definitions were also made using presenting visual acuity (VA). VI also was classified as unilateral (affecting one eye) or bilateral (affecting both eyes).

### Statistical Analysis

All statistical analyses was performed using Stata (ver. 10.0; StataCorp., College Station, TX). The 5-year incidence estimates of VI and blindness standardized by age and sex were calculated. To facilitate comparison with other studies, univariate and multivariate logistic regression models were used to investigate the associations of incident VI (WHO and US definitions) with potential risk factors, such as age, sex, education, income, insurance status, hypertension, diabetes, and baseline PVA. Only those variables significant at the 0.05

level in univariate analyses were included in the multiple logistic models. A *P* value of <0.05 was defined as indicating statistical significance.

### RESULTS

Among the 1405 subjects examined in 2003, 924 (75.0% of 1232 survivors) returned for the follow-up examination in 2009, whereas 173 (12.3%) subjects died and 308 (25.0%) survivors did not return for reexamination. Among participants in the follow-up examination, the mean age was  $63.4 \pm 9.0$  years and 530 (57.4%) were female. Participants were significantly younger than nonparticipants ( $63.4 \pm 9.0$  vs.  $66.4 \pm 10.6$  years,  $P < 0.001$ ), and were more likely to have hypertension (43.9% vs. 32.2%,  $P = 0.001$ ) and diabetes (11.4% vs. 6.64%,  $P = 0.032$ ), and less likely to have baseline presenting VI (PVI, WHO definition 2.71% vs. 8.77%,  $P < 0.001$ ) and best-corrected VI (WHO definition 17.6% vs. 28.3%,  $P < 0.001$ ), but there were no significant differences between these groups in terms of sex, educational status, income, and history of cataract surgery.<sup>10</sup>

According to WHO criteria, the incidence of best-corrected VI was 0.56% among persons 50 to 59 years, which increased to 12.7% among subjects  $\geq 70$  years ( $P < 0.001$ ), with an overall incidence of 5.38% (95% confidence interval [CI] = 3.99%, 7.07%). Corresponding figures for PVI were 4.09% and 25.9% for persons 50 to 59 and  $\geq 70$  years of age, respectively ( $P < 0.001$ ), with an overall incidence of 12.4%. The incidences of best corrected and presenting blindness were both 0.33%. Men and women had similar incidence of VI and blindness ( $P > 0.05$ , Table 1)

The incidences of best corrected visual impairment (BCVI) and PVI according to the US definition were 9.85% (95% CI = 7.96%, 12.0%) and 20.6% (95% CI = 17.7%, 23.6%), respectively, while the corresponding figures for best corrected and presenting blindness were 1.42% (95% CI = 0.76%, 2.41%) and 1.77% (95% CI = 1.02%, 2.86%, Table 1).

The overall 5-year incidence of VI in either eye (WHO standard based on BCVA) was 11.7%, and among persons aged 50 to 59, 60 to 69, and 70 years and above it was 3.06%, 11.5%, and 24.6%, respectively, increasing significantly with age ( $P <$

TABLE 2. Factors Associated With Incident Best-Corrected VI

Factor	VI, WHO Definition (95% CI)		VI, US Definition (95% CI)	
	Univariate Analysis	Multivariate Analysis	Univariate Analysis	Multivariate Analysis
Total N				
Age, ≥69 vs. <69 y	7.14 (3.71, 13.7)*	3.92 (1.90, 8.08)*	8.67 (5.23, 14.4)*	6.30 (3.13, 12.7)*
Female sex	0.88 (0.49, 1.58)	0.59 (0.30, 1.18)	1.01 (0.65, 1.59)	0.85 (0.42, 1.72)
Education, none	4.01 (2.19, 7.33)*	2.36 (1.15, 4.85)†	3.86 (2.40, 6.20)*	2.56 (1.23, 5.33)†
Low income, <1000 RMB/mo	1.30 (0.47, 3.57)		2.39 (1.10, 5.16)†	1.54 (0.65, 3.65)
Insurance, none	-		0.90 (0.31, 2.58)	
Hypertension, present	0.82 (0.45, 1.50)		1.00 (0.64, 1.57)	
Diabetes, present	1.20 (0.49, 2.90)		1.12 (0.56, 2.26)	
Baseline PVA in better-seeing eye, logMAR	9.91 (5.82, 16.9)*		9.78 (5.92, 16.2)*	
Baseline PVA in worse-seeing eye, logMAR	2.44 (1.90, 3.13)*	2.29 (1.73, 3.04)*	2.33 (1.86, 2.90)*	1.88 (1.37, 2.57)*

logMAR, log of the minimum angle of resolution.

\*  $P < 0.001$ .

†  $P < 0.05$ .

0.001). The overall 5-year incidence of monocular VI (WHO standard based on BCVA) was 6.17%, and among persons aged 50 to 59, 60 to 69, and 70 years and above it was 2.50%, 6.25%, and 11.5%, respectively, also increasing significantly with age ( $P < 0.001$ ).

In univariate logistic regression models, subjects with incident bilateral BCVI (WHO definition) were significantly older ( $P < 0.001$ ), less-educated ( $P < 0.001$ ), had poorer PVA at baseline in the worse-seeing eye ( $P < 0.001$ ), and better-seeing eye ( $P < 0.001$ ) than persons without incident VI. No associations were found between incident VI and sex, income, insurance status, and presence of hypertension or diabetes. In multivariate logistic regression models, incident VI was associated significantly with older age ( $P < 0.001$ ), less education ( $P = 0.016$ ), and poorer PVA at baseline in the worse-seeing eye ( $P < 0.001$ , Table 2). Regression results for PVI were similar, as were those using the US VI and blindness cutoffs (Tables 2, 3).

Using the WHO definition, the main causes of incident best-corrected VI were cataract (31 subjects, 64.6%), myopic macular degeneration (3 subjects, 6.25%), glaucoma (2 subjects, 4.17%), and diabetic macular edema (2 subjects, 4.17%, Table 4). The main causes of PVI were refractive error (40 subjects, 40.4%), cataract (38 subjects, 38.4%), and age-related macular degeneration (8 subjects, 8.08%). Of the 3 subjects with blindness, one was due to cataract, one age-

related macular degeneration, and one could not be determined.

The main causes of incident BCVI (US definition) were cataract (52 subjects, 60.5%), myopic macular degeneration (9 subjects, 10.5%), and age-related macular degeneration (7 subjects, 8.14%), while the main causes of PVI were refractive error (69 subjects, 43.9%), cataract (57 subjects, 36.3%), and age-related macular degeneration (10 subjects, 6.37%, Table 4).

### DISCUSSION

To our knowledge, this is the first study to document the five-year incidence of VI and blindness in urban southern China. Incident VI and blindness were very common in this population, and the major causes were cataract and refractive error. These data have important implications in planning public health strategies for urban China, where government health insurance is widely available.

Though such comparisons can be made only with caution due to differences in study design and definitions, our incidence estimates were higher than those reported by the Beijing Eye Study (BES),<sup>7</sup> the Los Angeles Latino Eye Study (LALES),<sup>11</sup> and the Reykjavik Eye Study,<sup>12</sup> but somewhat lower than for the Barbados Eye Study,<sup>13</sup> which did not reflect a purely urban population. Though age-enrollment criteria

TABLE 3. Factors Associated With Incident PVI

Factor	VI, WHO Definition, OR (95% CI)		VI, US Definition, OR (95% CI)	
	Univariate Analysis	Multivariate Analysis	Univariate Analysis	Multivariate Analysis
Total N				
Age, ≥69 vs. <69 y	4.15 (2.69, 6.40)*	3.19 (1.97, 5.19)*	4.21 (2.90, 6.12)*	3.33 (2.02, 5.47)*
Female sex	1.11 (0.72, 1.69)	0.96 (0.60, 1.55)	1.03 (0.72, 1.48)	0.82 (0.50, 1.34)
Education, none	2.37 (1.47, 3.82)*	1.36 (0.78, 2.38)	2.50 (1.64, 3.80)*	2.06 (1.12, 3.76)†
Low income, <1000 RMB/mo	1.76 (0.89, 3.48)		2.04 (1.18, 3.53)†	1.63 (0.90, 2.94)
Insurance, none	0.51 (0.15, 1.69)		1.14 (0.53, 2.44)	
Hypertension, present	1.17 (0.76, 1.79)		1.16 (0.81, 1.67)	
Diabetes, present	1.12 (0.57, 2.21)		1.56 (0.91, 2.67)	
Baseline PVA in better-seeing eye, logMAR	51.6 (20.9, 127)*		69.7 (28.8, 169)*	
Baseline PVA in worse-seeing eye, logMAR	1.94 (1.54, 2.45)*	1.80 (1.39, 2.32)*	1.86 (1.47, 2.35)*	1.35 (0.99, 1.84)

OR, odds ratio.

\*  $P < 0.001$ .

†  $P < 0.05$ .

TABLE 4. Causes of Incident VI

	WHO Definition, N (%)		US Definition, N (%)	
	BCVI	PVI	BCVI	PVI
Cataract	31 (64.6)	38 (38.4)	52 (60.5)	57 (36.3)
Myopic degeneration	3 (6.25)	2 (2.02)	9 (10.5)	3 (1.91)
Glaucoma	2 (4.17)	2 (2.02)	3 (3.49)	3 (1.91)
Diabetic macular edema	2 (4.17)	2 (2.02)	2 (2.33)	3 (1.91)
Refractive error	1 (2.08)	40 (40.4)	1 (1.16)	69 (43.9)
Optic nerve atrophy	1 (2.08)	2 (2.02)	1 (1.16)	2 (1.27)
Age-related macular degeneration	0 (0)	8 (8.08)	7 (8.14)	10 (6.37)
Diagnosis undetermined	8 (16.7)	5 (5.05)	11 (12.8)	9 (5.73)

differed among these studies, the age-specific incidence of visual impairment using the US criterion among persons 50 to 59, 60 to 69, and 70+ years in Liwan were 2.51%, 6.03%, and 25.9%, respectively (Table 1). These were higher than the corresponding figures for LALES (1.9%, 3.5%, and 10.6%), Reykjavik (0.33%, 1.66%, and 10.1%), and BES (0.8%, 2.8%, and 4.7%). All of these figures represent a 5-year incidence, except for LALES, which reports a 4-year incidence. (See also the Figure for VI incidence according to WHO criteria.)

To the best of our knowledge, BES is the only study to report the incidence of blindness and VI in China previously. The lower rates of VI in Beijing compared to Liwan are surprising given that our cohort had a higher 5-year incidence of cataract surgery than reported for BES (4.84% vs. 2.01%).<sup>14</sup> Furthermore, our study participants were urban residents, whereas the BES sample included a mixture of urban and rural dwellers in northern China. It is possible that this reflects methodologic differences between the studies, or previously unreported genetic, environmental or healthcare service delivery differences between these areas and populations.

The significant association of age with incident VI and blindness is not surprising, and is of importance to program planners giving the aging population. The significant association of incident VI with lower education also is important from the standpoint of intervention and policy making. First, educational efforts aimed at this population may increase

uptake of vision services. Second, it suggests that there is a significant inequality in the access to eye care services between the well- and poorly-educated, and highlights the need for social and health policies to ameliorate this gap. In view of the fact that at the time of baseline enrollment, undereducated persons were somewhat underrepresented in the cohort, it must be understood that these analyses depend on the assumption that those undereducated persons participating in our study are representative of those in the entire Liwan population.

Undercorrected refractive error (URE) was the leading cause of presenting blindness and VI. This is consistent with previous reports from China<sup>7</sup> and elsewhere.<sup>15</sup> The finding that more than half of the subjects with PVI could improve vision with an accurate pair of spectacles has important public health implication in China, where the costs of refractive correction still are not covered by the urban health insurance system (BSMIS). The cost of a good-quality spectacle frame and lenses still may present a cost barrier to some patients. Our findings suggested the need for population screening, education, and low-cost refractive correction to encourage the use of spectacles. As in many other populations,<sup>16-21</sup> age-related cataract was the most frequent cause of best-corrected VI in our study. Even though the cataract surgical rate for Chinese cities is well above the current national figure (772 cases per million population).<sup>22</sup> Our data suggested that current output is insufficient even in well-off urban areas, such as Guangzhou. This is complicated by the fact that blindness (US definition) remains in over 15% of patients undergoing cataract surgery in the Liwan population,<sup>23</sup> a figure that is comparable to the overall prevalence of such poor results in Zhao's population-based 9-province survey (23.5%).<sup>24</sup>

Potential limitations of our study should be addressed. First, the participation rate (75% of all survivors) was relatively low and may be a potential source of bias. Further, there is a lack of information regarding the participants' health literacy, quality of life, and awareness of eye care services. These factors may have influenced the uptake of eye service and contributed to VI. Though only one senior ophthalmologist (MH) performed the examinations and made diagnoses in this study, bias was controlled by making diagnoses on the basis of a 16-item diagnostic checklist (Supplementary Table S1). Furthermore, this senior ophthalmologist had been demonstrated to have very good agreement ( $\kappa = 0.82$ ) with experienced ophthalmologists at Moorfields in key elements of the ophthalmic exam in previous studies.<sup>9</sup> Finally, the study population is only

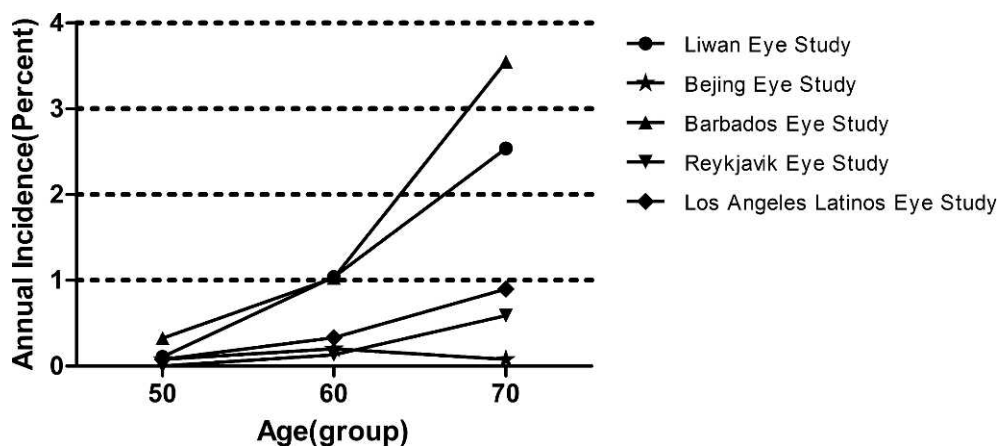


FIGURE. Comparison of annual incidence of BCVI (WHO definition) across five studies stratified by age.



representative of the permanent city residents in one neighborhood in southern China, and may not be similar to those living in other geographic areas. Limitations regarding our choice of this population, including peculiarities of the selected district, and the fact that age and sex of participants did not reflect perfectly those selected to take part at baseline, have been discussed in detail previously.<sup>9</sup> At the time of the current, 5-year follow-up examination, participants were younger than nonparticipants, and had more systemic comorbidities and less VI, all of which must be considered in applying these results more widely to other populations.

In conclusion, our study showed that the incidence of VI in this urban southern Chinese population is quite high compared to urban areas in other parts of the world. Undercorrected refractive error and unoperated cataract remain the leading causes of incident PVI, highlighting the need to improve access to cataract surgical and refractive services even in this urban setting. This presents a major public health challenge for China, with important implications for the country's 690 million urban-dwellers, a rapidly-growing population.

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