Rapid assessment of avoidable blindness including diabetic retinopathy in Queretaro, Mexico

Evaluación rápida de la ceguera evitable, incluida la retinopatía diabética, en Querétaro, México

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Abstract

Objective: To determine the prevalence and causes of blindness and visual impairment and the prevalence of diabetes and diabetic retinopathy (DR) in the state of Queretaro, Mexico. **Materials and Methods:** 180 clusters of 35 people aged ≥ 50 years were randomly selected. Participants had their visual acuity measured and lens examined and had a random blood glucose test to assess their diabetes status. Participants with diabetes had a dilated fundus examination and digital fundus photographs taken. DR was graded using the Scottish DR grading system. **Results:** The prevalence of blindness among the 5935 survey participants was 1.0% (95% confidence interval [CI]: 0.7-1.2%). The sample prevalence of severe, moderate, and early visual impairment and functional low vision were 1.6%, 3.2%, 12.7%, and 1.4%, respectively. The most common cause of blindness was cataract representing 29.8% of the cases, followed by DR (17.5%). The most common cause of functional low vision was DR (32.9%). There were 1115 participants with diabetes (18.8%, 95% CI: 17.4-20.2%), 92 of whom were newly diagnosed during this study. The prevalence of retinopathy and/or maculopathy among these patients was 22.5% (95% CI: 19.0-26.1%), and 3.6% (95% CI: 2.4-4.8%) had sight-threatening DR. **Conclusion:** Although cataract is the primary cause of blindness among people aged ≥ 50 years in Queretaro, Mexico, DR is the second cause of blindness and the leading cause of functional low vision. There is a need to expand and improve eye care services in Queretaro and to ensure early diagnosis and treatment of diabetes and DR.

Key words: Epidemiology. Blindness. Vision disorders. Diabetic retinopathy. Cataract. Mexico

Resumen

Objetivo: Determinar la prevalencia y las causas de ceguera y deficiencia visual así como la prevalencia de diabetes y retinopatía diabética (RD) en Querétaro, México. **Material y Métodos:** Se realizó un muestreo aleatorio en 180 conglomerados de 35 personas de ≥ 50 años. Se evaluó la agudeza visual y el estado del cristalino, del polo posterior, y de la diabetes (basado en la glicemia al azar). Se hizo un examen ocular a todos con diagnóstico de diabetes y se tomó fotografías digitales del fondo del ojo. Se utilizó la clasificación escocesa de RD. **Resultados:** La prevalencia de ceguera entre los 5.935 participantes fue del 1,0% (intervalo de confianza [IC] de 95%: 0,7%-1,2%). La prevalencia de la deficiencia visual severa, moderada, temprana y de baja visión funcional fueron de 1,6%, 3,2%, 12,7%, y 1,4%, respectivamente. La catarata era la

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causa principal de ceguera (29,8%), seguido de RD (17,5%). La RD era la causa principal de baja visión funcional (32,9%). En esta muestra, 1.115 participantes tenían diabetes (18,8%; IC de 95%: 17,4%-20,2%). Se identificaron 92 casos nuevos. La prevalencia de retinopatía y/o maculopatía entre estos pacientes diabéticos fue del 22,5% (IC de 95%: 19,0%-26,1%) y el 3,6% (IC de 95%: 2,4%-4,8%) presentó una RD con amenaza para la visión. **Conclusión:** A pesar de que la catarata es la causa principal de ceguera entre las personas de ≥ 50 años en Querétaro, México; la RD es la segunda causa de ceguera y la causa principal de baja visión funcional. Hay una necesidad de ampliar y mejorar los servicios oftalmológicos y asegurar el diagnóstico y el tratamiento temprano de diabetes y de RD en Querétaro.

Palabras claves: Epidemiología. Ceguera. Impedimento visual. Retinopatía diabética. Catarata. México

Introduction

The national prevalence of blindness in Mexico is estimated to vary from 0.4% to 1.5%, and 2.4% to 7.0% of the population has visual impairment.^{1,2} The wide range in prevalence rates can be attributed to the limited number of ophthalmic epidemiological studies available in Mexico, with only 3 studies previously carried out in 2 states: a Rapid Assessment of Cataract Surgical Services (RACSS) study in Nuevo Leon in 2005,^{3,4} a Rapid Assessment of Avoidable Blindness (RAAB) in Chiapas in 2010,⁵ and a follow-up RAAB study in Nuevo Leon in 2014 (unpublished). According to the World Bank, Mexico is considered to be an upper middle income country,⁶ but 55.3 million people (46.2% of the population) were living in poverty in 2014, and 21.8 million people (18.2% of the population) had no access to health services.⁷ In the northern state of Nuevo Leon, which is the least impoverished state (with 20.4% of the population living in poverty, or approximately 1 million people) of the 31 states and the federal district,⁷ the prevalence of blindness among the population aged 50 years and older was estimated to be 1.5%, and the prevalence of visual impairment was 8.8% in 2005.³ In the southern, most impoverished state of Chiapas, where 76.2% of the population (approximately 4 million people) is living in poverty,⁷ the prevalence of blindness among the population aged 50 years and older was 2.3%; the prevalence of moderate and severe visual impairment were 7.3% and 1%, respectively.⁵

In addition to the need to provide greater attention to eye health services in Mexico, diabetes is now an alarming public health crisis. There are 11.5 million people with diabetes in Mexico (15.8% of the population), 33.9% of whom are undiagnosed.⁸ With the diabetes epidemic, there is an emerging serious threat to vision loss that requires urgent action, as the prevalence of diabetic retinopathy (DR) is little known, particularly in developing settings.⁹ The RAAB + DR rapid methodology estimates the prevalence of diabetes, DR, and sight-threatening

DR in the population aged 50 years and older and also assesses the known and unknown status of diabetes among survey participants and the proportion of the participants with known diabetes who have had a fundus examination and who have glycemic control.⁹ The RAAB study in Chiapas was the first one in the Latin American region that incorporated a DR module.⁵ The authors found that the prevalence of diabetes was 21.3% in Chiapas; 38.9% of the population with diabetes had DR, and 21.8% had sight-threatening DR.

Diabetes is the first cause of death in the central state of Queretaro, where 15,000 people are registered with diabetes, only 42% of whom regularly receive care.¹⁰ Until now, the prevalence of blindness and visual impairment in the state was not known. In 2015, a RAAB + DR study was undertaken to determine the prevalence and causes of blindness and visual impairment and the prevalence of diabetes and DR in the state of Queretaro.

Materials and methods

In 2015, the International Agency for the Prevention of Blindness (IAPB)/VISION 2020 Latin America program organized a RAAB in the Mexican state of Queretaro in collaboration with the Mexican Institute of Ophthalmology (IMO, the Spanish abbreviation). The study was funded by the IAPB, Orbis International, and Bayer AG. The ethics and research committees of the IMO approved the research protocol, which was carried out in accordance with the Declaration of Helsinki. Study participants provided their written or verbal informed consent.

Given that no ophthalmic epidemiological survey was previously performed in Queretaro, and the state's population is among the wealthier of Mexico,⁷ the prevalence rate of blindness plus visual impairment of 2.3% obtained from the 2014 RAAB study in Nuevo Leon was used to calculate the sample size. A required sample

size of 6,270 participants was estimated based on the expected visual impairment prevalence of 2.3% among adults aged 50 years or older, a precision of 20%, a confidence of 95%, a design effect of 1.4, and a 10% nonresponse rate. There were 180 clusters of 35 people aged 50 years or older included.

The sampling frame was based on the 2010 data from the national census.¹¹ Probability proportionate to size sampling was used to select 180 small population units. Given that 14.5% of the population was aged 50 years or older, a cluster of 35 people aged 50 years or older could be obtained from a segment of approximately 241 people of all ages. Each of the selected population units was subdivided in segments of approximately 250 people of all ages, and 1 segment was randomly selected as the cluster. Among the 180 clusters, 69 (38.3%) were in rural communities and 62% (111) were in urban communities. According to 2010 census data, 30% of the state population is rural and 70% is urban;¹² thus, this survey drew upon a larger population from remote and underserved communities.

All households in each of the 180 clusters were surveyed door-to-door until 35 people of 50 years or older were identified. If the target number was not reached within a selected segment, then another segment in the same population unit was randomly selected to continue the sampling until 35 eligible people were identified.

Survey teams

Five teams of 3 IMO staff members each were trained on the RAAB + DR methodology at the IMO and carried out the surveys. Each team included 1 general ophthalmologist/retinal fellow (5 total) and 2 residents (10 total). A certified RAAB trainer trained the teams over a 1-week period. After the training and prior to conducting the survey, an interobserver agreement assessment on visual acuity, lens, main cause of visual impairment or blindness and the primary cause (if any), and DR grading was conducted and evaluated to ensure that potential variation was acceptable (i.e., $\kappa > 0.6$). All Kappa coefficient values were ≥ 0.77 , indicating good to very good agreement.

Ophthalmic examination

Snellen tumbling E charts of size 60, 18, and 12 were used to measure presenting visual acuity (PVA) in full daylight. Pinhole vision was assessed for eyes with VA $< 20/40$. The following definitions of blindness and visual impairment were applied, based on the better eye:

blind (PVA $< 20/400$), severe visual impairment (PVA $< 20/200$ - $20/400$); moderate visual impairment (PVA $< 20/60$ - $20/200$),¹³ and early visual impairment (PVA $< 20/40$ - $20/60$). An ophthalmologist used a flashlight and direct ophthalmoscope in a shaded area to assess the lens. Eyes with PVA $< 20/40$ were examined with a direct ophthalmoscope to determine the primary cause of visual impairment. Participants with BCVA $< 20/200$ due to cataract were asked the reason why they had not undergone cataract surgery, and those who were operated on for cataract had their surgical data recorded.

Diabetes and DR assessment (DR module)

Survey team members asked participants if they had a diabetes diagnosis by a health professional and if they were taking medication for diabetes. They then performed a random blood glucose (RBG) test on consenting participants using a glucose meter (Accu-Chek Performa, Roche Diagnostics, USA). Participants were considered to have diabetes if they had a previous confirmed diagnosis or had an RBG level ≥ 200 mg/dl. Those with known diabetes answered additional questions regarding type of treatment, whether they were advised by a health professional to undergo an eye examination because of their diabetes, and when their last diabetes-related eye examination was.

In a darkened room in the household, a retinal fellow performed a clinical dilated fundus examination with a direct and indirect ophthalmoscope using a 20-diopter lens on all consenting participants identified as having diabetes to determine the presence and grade of DR. The Scottish DR grading classification was used.¹⁴ Participants with diabetes were also referred to the IMO to have a digital fundus photograph taken using a nonmydriatic retinal camera (Volk Pictor Plus, Volk Optical, USA), with DR grading confirmed by a retinal fellow.

Statistical analysis

All survey records were entered in the RAAB software using the data entry module with built-in validation to minimize data entry errors. After cleaning the data, the automated data analysis of the RAAB6 software was used to generate the standard reports,¹⁵ which includes analysis for the DR module. Nonresponders were excluded from analysis. Confidence intervals (CIs) were calculated based on the cluster sampling design. The cataract surgical coverage was calculated based on the proportion of people and eyes with operable

cataract who underwent cataract surgery, with the assumption that only individuals with VA levels worse than 20/400, 20/200, and 20/60 undergo surgery.

Results

Field work for this study was performed between July 2015 and June 2016. The survey included 6,300 people aged 50 years or older, 5,935 of whom were examined (2,769 men and 3,166 women). The sex and age composition of the sample was comparable to that of the census data. Coverage was 94.2%; 325 (5.2%) refused to participate in the study, 25 people (0.4%) were absent, and 15 (0.2%) were not able to undergo the examination.

Prevalence and causes of blindness and visual impairment

The prevalence of bilateral blindness with available correction (PVA) in the better eye among the study sample population aged 50 years and older was 1.0% (95% CI: 0.7%-1.2%) (Table 1). The prevalence of blindness among men was 1.1%, which was similar to the prevalence among women (0.9%). The prevalence rates of severe visual impairment, moderate visual impairment, and early visual impairment were 1.6% (95% CI: 1.3%-1.9%), 3.2% (95% CI: 2.7%-3.8%), and 12.7% (95% CI: 11.2%-14.1%), respectively. The prevalence of functional low vision that requires low vision services was 1.4% (95% CI: 1.1%-1.7%). There was no significant difference in prevalence among men and women (Table 1). The prevalence of blindness increased with age, with only 0.4% (95% CI: 0.2%-0.6%) of participants aged 50-59 years having blindness vs 7.3% (95% CI: 3.9%-10.6%) of participants aged 80 years and older. After extrapolating to the age and gender distribution of the state of Queretaro, an estimated 3,853 people aged 50 years and older (1.1%) are thought to have bilateral blindness, including 1,754 men and 2,097 women.

The causes of blindness and visual impairment among the study sample population are summarized in Table 2. Cataract represented 29.8% of the cases of blindness and was the most common cause of blindness, followed by DR (17.5%), and other posterior segment diseases (15.8%). Posterior segment diseases, including DR and glaucoma, comprise 40.3% of all cases of blindness, with DR being the most frequent posterior segment disease and the second most frequent cause of blindness.

Refractive error is the cause of 14.9% of severe visual impairment, 28.6% of moderate visual impairment, and 81.8% of early visual impairment. However, cataract is still the major cause of severe visual impairment (43.6%) and moderate visual impairment (39.1%) (Table 2).

The most common cause of functional low vision is DR (32.9%), followed by other posterior segment diseases (23.2%), glaucoma (19.5%), cataract surgical complications (8.5%), age-related macular degeneration (6.1%), other corneal opacities (4.9%), other globe or central nervous system abnormalities (3.7%), and phthisis (1.2%).

In Queretaro, 79.0% of blindness is avoidable, 36.8% of which is treatable, 8.8% can be prevented by primary eye care services, and 33.3% can be prevented by specialized ophthalmic services.

Cataract

The prevalence of bilateral cataract blindness among the study sample was 0.2% (95% CI: 0.1%-0.3%, $n = 11$). Thirty-four people had severe visual impairment due to cataract (0.6%; 95% CI: 0.4%-0.8%), 69 had moderate visual impairment due to cataract (1.2%; 95% CI: 0.9%-1.5%), and 169 had early visual impairment due to cataract (2.9%; 95% CI: 2.4%-3.3%). The prevalence was similar among men and women. When adjusted by age and sex, an estimated 768 people in Queretaro are thought to have bilateral cataract blindness (443 men and 325 women).

The cataract surgical coverage rates are provided in Table 3; 74.5% of eyes with cataract blindness were operated on, and 91.7% of patients with cataract blindness had surgery in 1 or both eyes. Coverage was similar between men and women at all VA levels (Table 3). Almost all operated patients (98.4%) had an intraocular lens implanted. Among all eyes operated on for cataract, 68.1% had good to very good surgical outcomes with available correction; 47.0% had a VA >20/40; 21.1% had a VA >20/60; and 19.7% had poor outcomes and could not see 20/200 (Table 4). With pinhole correction, the outcomes improved to 77.3% having good to very good outcomes and 13.5% having a poor outcome (Table 4). Surgery/surgery-related complications were the main reason for poor or borderline surgical outcomes (63.9%), followed by poor case selection (24.7%) and uncorrected refractive error (11.3%).

Among all cataract surgeries performed, 62.8% were carried out in public hospitals, 28.3% in private hospitals, and 8.9% in charitable hospitals. Private

Table 1. Prevalence of blindness, severe, moderate and early visual impairment, and functional low vision among persons ≥ 50 years, with available correction and in the better eye, in Queretaro, Mexico, 2015

	Men (n = 2,769)		Women (n = 3,166)		Total (n = 5,935)	
	No.	Prevalence (95% CI)	No.	Prevalence (95% CI)	No.	Prevalence (95% CI)
Blindness (VA <20/400)	29	1.1 (0.6-1.5)	28	0.9 (0.6-1.2)	57	1.0 (0.7-1.2)
Severe visual impairment (VA <20/200-20/400)	46	1.7 (1.2-2.2)	48	1.5 (1.1-2.0)	94	1.6 (1.3-1.9)
Moderate visual impairment (VA <20/60-20/200)	91	3.3 (2.6-4.0)	101	3.2 (2.5-3.9)	192	3.2 (2.7-3.8)
Early visual impairment (VA <20/40-20/60)	380	13.7 (11.8-15.6)	371	11.7 (10.2-13.2)	751	12.7 (11.2-14.1)
Functional low vision ^a	44	1.6 (1.1-2.1)	38	1.2 (0.8-1.6)	82	1.4 (1.1-1.7)

CI = confidence interval; VA = visual acuity

^a Visual impairment (pinhole VA <6/18 – perception of light) that cannot be corrected by medical treatment, surgery, or conventional refractive correction (i.e., eyeglasses or contact lenses).**Table 2.** Principal causes of blindness and severe, moderate, and early visual impairment in persons ≥ 50 years with available correction in Queretaro, Mexico, 2015

Cause	Blindness ^a		Severe Visual Impairment ^b		Moderate Visual Impairment ^c		Early Visual Impairment ^d	
	No.	%	No.	%	No.	%	No.	%
Refractive error	4	7.0	14	14.9	55	28.6	614	81.8
Cataract, untreated	17	29.8	41	43.6	75	39.1	58	7.7
Cataract surgical complications	5	8.8	8	8.5	5	2.6	14	1.9
Trachoma	0	0.0	0	0.0	0	0.0	1	0.1
Other corneal opacities	4	7.0	0	0.0	1	0.5	2	0.3
Phtisis	1	1.8	0	0.0	0	0.0	0	0.0
Glaucoma	4	7.0	8	8.5	9	4.7	11	1.5
Diabetic retinopathy	10	17.5	11	11.7	22	11.5	16	2.1
Age-related macular degeneration	0	0.0	5	5.3	5	2.6	16	2.1
Other posterior segment disease	9	15.8	7	7.4	19	9.9	19	2.5
All other	3	5.3	0	0.0	1	0.5	0	0.0
Total	57	100.0	94	100.0	192	100.0	751	100.0

^aVisual Acuity <20/400^bVisual Acuity <20/200-20/400^cVisual Acuity <20/60-20/200^dVisual Acuity <20/40-20/60

hospitals had a slightly larger proportion of eyes with good/very good outcomes (68.7%), followed by public hospitals (68.1%) and charitable hospitals (66.6%). Charitable hospitals had the lowest proportion of poor outcomes (14.8%), followed by public hospitals (18.8%) and private hospitals (23.3%). These differences were not significant. Risk adjustment was not performed, which may affect the interpretation of

these results, as in many settings, more complicated cases are often referred to public/university hospitals. Therefore, it is possible that the public hospitals received the most difficult and hard-to-operate cases.

Participants with severe visual impairment and blindness due to bilateral cataract were asked why they had not been operated. Their reasons they mentioned

Table 3. Cataract surgical coverage, by eyes and by persons, in Queretaro, Mexico, 2015

Cataract Surgical Coverage	Men (%)	Women (%)	Total (%)
Visual acuity level (eyes)			
<20/400	74.4	74.6	74.5
<20/200	64.3	63.4	63.9
<20/60	54.1	49.5	51.8
Visual acuity level (persons)			
<20/400	90.4	93.2	91.7
<20/200	79.5	77.3	78.5
<20/60	67.0	63.3	65.2

Table 4. Postoperative visual outcomes of eyes operated on for cataract in persons ≥ 50 years in Queretaro, Mexico, 2015

Visual Outcome	Available correction		Pinhole correction	
	No.	%	No.	%
Very good; can see 20/40	143	47.0	184	60.5
Good: can see 20/60	64	21.1	51	16.8
Borderline: can see 20/200	37	12.2	28	9.2
Poor: cannot see 20/200	60	19.7	41	13.5
Total	304	100.0	304	100.0

for not undergoing cataract surgery were: “cannot afford” ($n = 18$, 38.3%), “fear of surgery or poor outcome” ($n = 11$, 23.4%), “need not felt” ($n = 7$, 14.9%), “no access to treatment” ($n = 5$, 10.6%), “unaware that treatment is possible” ($n = 4$, 8.5%), “treatment denied by the provider” ($n = 1$, 2.2%), and “local reasons” ($n = 1$, 2.2%). The barriers were similar among men and women.

Diabetes and DR

Among the study sample, 1,115 participants had diabetes (18.8%; 95% CI: 17.4%-20.2%), including 452 men (16.4%; 95% CI: 14.6%-18.0%) and 663 women (20.9%; 19.2%-22.7%). Among these participants with diabetes, 1,023 (91.7%) were previously diagnosed with diabetes, and 92 (8.3%) were newly diagnosed during the study and were previously unaware that they had diabetes. The prevalence was significantly higher in females ($p < 0.05$). The highest prevalence rate was among those aged 60-69 years (22.2%; 95% CI: 20.0%-24.3%).

There were 4,150 people (69.9%) who consented to the RBG test, and 1,785 (30.1%) refused to have their blood examined. There were 182 participants with known diabetes (17.8%) who refused to take the RBG test. Among participants with known diabetes who took the RBG test, 36.6% ($n = 308$) had a RBG level

≥ 200 mg/dl, indicating that more than a third had poor glycemic control.

Among participants with known diabetes ($n = 1,023$), the mean age at diagnosis was 62 years (range: 1-80 years), and the mean duration of the disease was 11 years (range: 0-80 years).

The diabetes treatment regimen and time of last eye exam for DR among participants with known diabetes are summarized in Table 5. Most participants ($n = 693$; 67.7%) reported to take tablets as treatment, and 93 (9.1%) took tablets combined with insulin. Eight percent ($n = 82$) did not report any treatment, while 4.4% ($n = 45$) mentioned their diet was the only way they managed their diabetes. Most participants with known diabetes ($n = 599$; 58.6%) never had an eye exam to assess for DR, 28.7% ($n = 294$) had an exam within the past year and 8.5% ($n = 87$) had an exam more than 2 years ago (Table 5).

Among the 1,023 participants with known diabetes, 521 (50.9%) agreed to dilatation and fundus examination. Among the 92 participants with diabetes newly diagnosed, 41 (44.6%) agreed. The prevalence of DR among all participants with diabetes and in the total study population is summarized in Table 6. In the total study sample, the prevalence of retinopathy was 4.2% (95% CI: 3.5-5.0%); 1.6% (95% CI: 1.3%-2.0%) had maculopathy, and 4.2% (95% CI: 3.5%-5.0%) had retinopathy and/or maculopathy (Table 6). The prevalence

Table 5. Treatment and time of last eye exam for diabetic retinopathy among persons with known diabetes in Queretaro, Mexico, 2015

	Men		Women		Total	
	No.	%	No.	%	No.	%
Treatment						
No treatment	37	8.8	45	7.5	82	8.0
Diet only	23	5.5	22	3.6	45	4.4
Tablets	280	66.8	413	68.4	693	67.7
Insulin	40	9.5	67	11.1	107	10.5
Tablets + insulin	38	9.1	55	9.1	93	9.1
Other	1	0.2	2	0.3	3	0.3
Total	419	100.0	604	100.0	1,023	100.0
Time of last eye exam						
Never	241	57.5	358	59.3	599	58.6
0-12 months ago	116	27.7	178	29.5	294	28.7
13-24 months ago	23	5.5	20	3.3	43	4.2
>24 months ago	39	9.3	48	7.9	87	8.5
Total	419	100.0	604	100.0	1,023	100.0

of sight-threatening DR in the sample population was 0.7% (95% CI: 0.4%-0.9%), and 0.8% (95% CI: 0.6%-1.1%) had laser scars.

Among the participants with diabetes, 22.5% (95% CI: 19.0%-26.1%) had retinopathy, 8.6% (95% CI: 6.8%-10.4%) had maculopathy, and 22.6% (95% CI: 19.1%-26.1%) had retinopathy and/or maculopathy (Table 6). The prevalence of sight-threatening DR was 3.6% (95% CI: 2.4%-4.8%), and 4.4% (95% CI: 3.1%-5.7%) had laser scars. More men (25.2%; 95% CI: 20.2%-30.3%) had DR than women (20.8%; 95% CI: 17.1%-24.5%). The prevalence of DR increased with age, with 15.7% of participants aged 50-59 years having any retinopathy and/or maculopathy versus 31.9% of the ≥80 year age group. The difference in prevalence among sexes and ages were not significant.

The subgroup with diabetes had significantly higher prevalence rates of blindness, severe, and moderate visual impairment than participants without diabetes. The prevalence of blindness among participants with diabetes was 2.3% (95% CI: 1.5%-3.2%; n = 26) versus 0.6% (95% CI: 0.4%-0.9%; n = 31) in participants without diabetes (p <0.05). The prevalence of severe visual impairment among the 2 groups was 2.8% (95% CI: 1.8%-3.7%; n = 31) and 1.3% (95% CI: 1.0%-1.6%; n = 63) (p <0.05) respectively. The prevalence of moderate visual impairment among the 2 groups was 6.8% (95% CI: 5.1%-8.6%; n = 76) versus 2.4% (95% CI: 2.0%-2.9%; n = 116) (p <0.05). There was no significant difference in the prevalence of early visual impairment among the 2 groups (14.3%; 95% CI: 11.8%-16.8%; n = 158 vs 12.3%; 95% CI: 10.9%-13.7%; n = 593).

Discussion

This study was the first population-based study of blindness and visual impairment in the state of Queretaro and the second RAAB + DR survey of DR in Mexico.⁵ Among the survey participants aged 50 years and older, the prevalence of blindness was 1.0%, with the principal cause of blindness being cataract (29.8%), followed by DR (17.5%). The most common cause of functional low vision was DR (32.9%). Almost 1 in 5 participants had diabetes; the majority knew they had the disease (91.7%), of whom more than one third had poor glycemic control, indicating suboptimal diabetes management. Among those with diabetes, 22.5% had retinopathy and/or maculopathy, and 3.6% had sight-threatening DR. However, only 4.4% had any evidence of previous treatment for DR.

The only other study in Mexico to have used the RAAB + DR methodology was in Chiapas in 2010.⁵ The prevalence of blindness in Chiapas was 2.5 times that of Queretaro,⁵ and cataract caused 63% of cases of blindness, whereas DR only made up 8% of cases. While cataract surgical coverage was high among patients with cataract blindness in Queretaro (91.7%), only 69% of patients with a VA <20/400 were operated on for cataract in Chiapas. The prevalence of diabetes was near equivalent in both states. Nonetheless, among the population with diabetes in Chiapas, the DR prevalence was nearly twice as high (38.9%), and 21% had sight-threatening DR.⁵ The vast differences in study results may be attributed to the high poverty rate (76.2%) and very limited availability of health and ophthalmic services in the remote state of Chiapas,^{5,7} whereas in Queretaro, approximately a third of the population lives

Table 6. Prevalence of diabetic retinopathy among people with diabetes and in the total study population in Queretaro, Mexico, 2015

Grade ^a	No.	People with Diabetes (n = 1,115), % (95% CI)	Total Study Sample (n = 5,935), % (95% CI)
DR grade			
No DR (R0)	311	27.9 (23.5-32.3)	5.2 (4.3-6.2)
Background DR: mild (R1)	150	13.5 (10.9-16.0)	2.5 (2.0-3.0)
Background DR: observable (R2)	48	4.3 (3.0-5.6)	0.8 (0.6-1.1)
Background DR: referable (R3)	13	1.2 (0.5-1.8)	0.2 (0.1-0.3)
Proliferative DR (R4)	31	2.8 (1.7-3.9)	0.5 (0.3-0.7)
Ungradable (R6)	9	0.8 (0.2-1.4)	0.2 (0.0-0.3)
Any retinopathy	251	22.5 (19.0-26.1)	4.2 (3.5-5.0)
Maculopathy grade			
No maculopathy (M0)	466	41.8 (36.4-47.2)	7.9 (6.7-9.10)
Maculopathy observable (M1)	59	5.3 (3.9-6.7)	1.0 (0.7-1.3)
Maculopathy referable (M2)	18	1.6 (0.8-2.4)	0.3 (0.2-0.5)
Ungradable maculopathy (M6)	19	1.7 (0.9-2.5)	0.3 (0.2-0.5)
Any maculopathy	96	8.6 (6.8-10.4)	1.6 (1.3-2.0)
Any DR and/or maculopathy	252	22.6 (19.1-26.1)	4.3 (3.5-5.0)
Sight-threatening DR (R4 and/or M2)	40	3.6 (2.4-4.8)	0.7 (0.4-0.9)
Any laser scars	49	4.4 (3.1-5.7)	0.8 (0.6-1.1)

CI = confidence interval; DR = diabetic retinopathy

^aThe Scottish grading classification was used. ¹³ Grading was performed by a trained retinal expert and based on fundus photographs. If the image was ungradable, the clinical diagnosis was used. If one eye was ungradable, the gradable eye determined the grade.

in poverty⁵ and the population is predominantly urban.¹² However, the national Mexican Health and Aging Study found that the combined prevalence of self-reported diabetes and undiagnosed diabetes was 39.4% among 2,012 participants,¹⁶ which is similar to the Chiapas prevalence rate. In the northeastern state of Coahuila, 68% (121/177) of patients with diabetes for at least 10 years had DR, which is considerably more than the 22.6% in Queretaro,¹⁷ but this study did not employ the RAAB methodology and so its results are not comparable with our current study. Furthermore, we do not know the duration of the disease in Queretaro. The lower prevalence in Queretaro combined with the fact that most participants were aware that they had diabetes would suggest that health services are more widely available in the state than at the national level and that the wealth of the population may be a factor.

More than half of the patient-reported cataract surgical barriers (51.1%) are related to the availability of services in Queretaro. Demographic trends suggest that the population of Mexico will increase from 19.2 million in 2010 to nearly 40 million in 2030, and the proportion of people aged 50 years and older will increase to 24%,¹⁸ doubling the demand for cataract surgeries. The cataract surgical rate in Queretaro will have

to increase by 10% a year to meet this demand. There is therefore an urgent need to expand and strengthen the eye health system in Queretaro, by prioritizing the accessibility of specialized ophthalmic services, cataract surgical services, and optical services, which together address 77.1% of the causes of blindness. This will have great impact on the visual health of the local population. Although services related to posterior segment diseases such as DR and glaucoma are costlier, these diseases cause approximately 40.3% of blindness in Queretaro and deserve special attention, especially when considering that 58.6% of participants with known diabetes never had an eye exam to evaluate for DR and only 4.4% of them had previous DR treatment. There is a need to improve diabetes and DR management, including the early diagnosis and treatment services. The development and expansion of optic, glaucoma, and low vision services are all required to better control for other posterior segment diseases.

This study also identified the need to improve visual outcomes following cataract surgery in Queretaro, with 68.1% of patients having good outcomes of presenting VA of 6/18 or better, while 19.7% had poor outcomes. Introducing routine monitoring of cataract surgical outcome may help to improve the visual outcome. Careful

patient selection may help to select those patients with multiple causes of visual impairment who are likely to benefit from cataract surgery. Good quality biometry and adequate optical services are essential to improve visual outcomes. Better quality cataract surgery will help to assuage the concerns of patients who are fearful to undergo cataract surgery, which was the second surgical barrier identified in this study.

Limitations

A major limitation of this cross-sectional survey was that only the population aged 50 years and older participated. The DR module in RAAB employs simplified examination methods to facilitate carrying out the survey in the household setting.⁹ Instead of using a fasting blood glucose or oral glucose tolerance test, RBG levels and having a history of diabetes are used to diagnose diabetes, which might underestimate the number of participants with diabetes. A simplified DR grading system (the Scottish grading system) was used to assess DR, which does not provide comprehensive information on the grade of DR.⁹ Furthermore, 30.1% of the survey participants did not consent to the RBG test, including 17.8% of participants with known diabetes. Therefore, the prevalence of diabetes and DR may be underestimated in the sample population of this study.

More than half of the participants with diabetes (54.9%) refused the DR examination. Consequently, the assessment of the prevalence and grades of DR in the population with diabetes is less representative and less accurate. Furthermore, the estimate of the prevalence of DR in the entire sample is very likely underestimated and could well be twice as high. Future RAAB studies should consider better promoting the RAAB methodology and the implications of participation in the selected communities prior to initiating field work, so that there is better awareness and understanding among potential participants, which could result in greater participation uptake for the diabetes component.

Conclusions

Although cataract is the primary cause of blindness among people aged 50 years and older in Queretaro, Mexico, DR is the second cause of blindness and the leading cause of functional low vision. Almost 1 in 5 people in Queretaro have diabetes, of whom, more than 1 in 5 have DR. The prevalence of retinopathy was nearly 4 times the prevalence of blindness in the study sample, yet most participants with diabetes had never

had an eye exam. There is a need not only to expand and improve eye care services in Queretaro, but also to ensure early diagnosis and adequate treatment of diabetes and DR before thousands of people in the state unnecessarily lose their sight.

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Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

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Conflict of interest

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Authorship

All authors have read and approved the manuscript, and their requisites for authorship have been fulfilled.

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