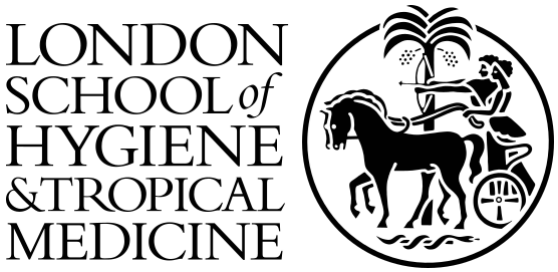

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Prevalence and service assessment of cataract in Tibetan areas of Sichuan Province, China: population-based study

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ABSTRACT

Objectives To assess the prevalence of visual impairment (VI) and blindness (BL) due to cataract and cataract surgical outcomes in remote dispersed and high-altitude Tibetan areas of China.

Design and setting A cross-sectional study was conducted among people aged 50 and above in Tibetan Autonomous Prefecture of Kandze (TAPK), China, in 2017. The Rapid Assessment of Avoidable Blindness protocol was followed.

Participants Of 5000 eligible participants, 4764 were examined (response rate 95.3%).

Primary and secondary outcome measures Cataract VI was defined as lens opacity at visual acuity (VA) levels of <3/60 (Blindness (BL)), ≥3/60 and <6/60 (severe visual impairment (SVI)), ≥6/60 and <6/18 (moderate visual impairment (MVI)), ≥6/18 and <6/12 (early visual impairment (EVI)).

Results The estimated prevalence of cataract BL was 0.61% (95% CI 0.42 to 0.87). With best corrected VA, the estimated prevalence of SVI from cataract was 0.86% (95% CI 0.63 to 1.17); MVI was 2.39% (95% CI 2.00 to 2.87) and EVI was 5.21% (95% CI 4.61 to 5.87). Women in TAPK had a significantly higher prevalence of cataract BL (0.82%, 95% CI 0.54 to 2.15) than men (0.34%, 95% CI 0.16 to 0.70). Women had lower cataract surgical coverage (CSC) by eyes (60.8%, 95% CI 55.5 to 65.8) compared with men (70.1%; 95% CI 63.7 to 75.7). The prevalence of cataract BL was higher among Tibetan (2.28%; 95% CI 1.98 to 2.62) than Han Chinese (1.01%%; 95% CI 0.54% to 1.87%). Overall CSC by person with BL (by better eye) was 82.0% (95% CI 75.2 to 87.6). Among cataract-operated participants, 71.2% had VA equal to or better than 6/18.

Conclusions The study detected a low prevalence of VI and BL due to cataract with high CSC in the study area compared with many other places in China. Further actions should be taken to improve cataract surgical outcome.

Strengths and limitations of this study

- The study had a large sample size which was accurately calculated to estimate the prevalence of blindness in the study area.
- A high response rate was achieved for the study, facilitated by door-to-door sampling, and community sensitisation in advance of the survey.
- High-quality data collection was facilitated in this remote and dispersed area through: (1) following the robust Rapid Assessment of Avoidable Blindness methodology; (2) using local survey teams; (3) using simple clinical tools; (4) an experienced survey specialist supervising study teams; (5) high diagnostic agreement between the two ophthalmologists in the two study teams (determined in an interobserver variation study).
- The study area is diverse in terms of altitude, distance to the eye health services and ethnicities. This made it possible to make comparisons between different groups in terms of prevalence and cataract services.
- The barriers to cataract surgery were explored using a single question with seven response options, and therefore we may not have captured the whole spectrum of possible barriers in this population.

BACKGROUND

The Vision Loss Expert Group at WHO has estimated that there are 253 million people worldwide with moderate or severe visual impairment (M/SVI) and blindness (BL), 80% of which is preventable or treatable.[1 2] Global initiatives, such as Vision 2020 (1999) and subsequent Global Action Plan for the Prevalence of Blindness and Visual Impairment (BL/VI) (2014–2019), have contributed substantial progress towards combating cataract BL.[1] The Global Burden of Disease study estimated that between 1990 and 2010, the crude prevalence of cataract-related BL and M/SVI decreased worldwide from 38.6% to 33.4% and from 25.6% to 18.4%, respectively.[3] Despite this, in 2017,[4] unoperated cataracts were still the leading cause of BL and SVI in low-income and middle-income countries and globally.[1]

Table 1 Characteristic of study subjects by examination status and minority, N (%)

	Enumerated	Examined
Ethnicity		
Tibetan	4323 (86.5)	4127 (95.5)
Han	523 (10.5)	495 (94.7)
Other	154 (3.08)	142 (92.2)
Age		
50–59 years	1896 (37.9)	1831 (96.6)
60–69 years	1662 (33.2)	1582 (95.2)
70–79 years	1091 (21.8)	1038 (95.1)
80+years	351 (7.02)	313 (89.2)
Sex		
Male	2177 (43.5)	2087 (95.9)
Female	2823 (56.5)	2677 (94.8)
Region		
Pastoral area	1173 (23.5)	1105 (94.2)
Agriculture area	3602 (72.0)	3440 (95.5)
Urban	225 (4.50)	219 (97.3)
Distance from hospital, km		
≤200	1600 (32.0)	1515 (94.7)
201–400	1500 (30.0)	1437 (95.8)
>400	1900 (38.0)	1812 (95.4)
Altitude of participants lived, metres		
≤2000	500 (10.0)	476 (95.2)
2001–3000	1450 (29.0)	1371 (94.6)
3001–4000	2550 (51.0)	2448 (96.0)
>4000	500 (10.0)	469 (93.8)
Total	**5000 (100.0)**	**4764 (95.3)**

In China, cataract also remains the leading cause of BL/VI among people 50 years and older, accounting for 35% of causes of BL and 67.1% of causes of VI.[5–7] Eighty-five per cent of BL/VI is experienced by people 50 years and older.[2] In the past 20 years, in addition to the routine cataract operations in hospitals, the national government has initiated a range of outreach programme to encourage city-based surgeons to conduct eye surgery, including cataract surgery, in rural county hospitals. A national cataract programme for low-income Chinese people has been implemented. This programme exempts the fee for surgery—typically 35%–50% of the total cost of surgery, and the remainder is covered by insurance so that patients receive free surgery. The programme sends experienced cataract surgeons from tertiary centres to county hospitals (secondary care) or township health centres (primary care) for cataract service delivery. Domestic and international organisations have also been encouraged to support training of eye health workers in screening and referral of cataract patients. These efforts have increased national average cataract surgical rate (CSR) per million people per year—from approximately 400 in the early 1990s to over 2300 in 2017.[8 9] In China, cataract surgical coverage (CSC) for blind eyes has been estimated to be approximately one-third[7 10]; for those with MVI (visual acuity (VA) ≥6/60, but <6/18), the rate varies from around 30% to 70%.[5–7 11]

Previous studies in North America, China and Australia have found the prevalence of cataract VI increases with increasing altitude due to higher levels of ultraviolet light exposure.[12–15] However, results are inconclusive in Tibetan areas.[16 17] Studies in Tibetan areas and various parts of the world have also found higher cataract prevalence in women compared with men. Prevalence also varies by ethnicity—with cataract being more prevalent among minority ethnic groups compared with the majority Han Chinese in China. Further, there is evidence that the prevalence of cataract is higher among those who live further from hospitals.[18] In China, evidence from several studies suggests that good cataract surgical outcome rates are broadly lower than the recommendations from WHO (with available correction, 80% postoperated eyes should have VA≥6/18).[7 19–21]

Tibetan Autonomous Prefecture of Kandze (TAPK) is located in western Sichuan Province, China. As part of Qinghai-Tibetan Plateau, the altitude in TAPK varies from over 1000 to 7556 m, with an average altitude of approximately 4000 m. The population of TAPK is 1.1 million,[22] 51.6% of whom are male. The vast majority (87.1%) of the population live in dispersed rural areas, and are engaged in farming activities. There are two main types of land in the area—arable, where people live in settled homes and farm crops, and pastoral, where people move regularly to seek pasture sources for cattle. There are small towns (urban) mainly in the centre of the county and the prefecture. Over 99% of the school-aged children in TAPK attend school. 16.7% of the population are aged 50 years and older. The majority of people are of Tibetan ethnicity (78.4%), the remaining being Han Chinese and other ethnic minority groups.

Kham Eye Center in the Kandze Prefecture People's Hospital (KEC) was founded in 1998 and is based in the capital city of TAPK. It is the only eye institute supplying eye services in the area. In 2017, the hospital completed approximately 2000 cataract operations and another 1000 cases through surgical outreach. This resulted in a CSR in TAPK of 3000 per million which was almost equal to the rate in some of the most developed areas of China.[21] The outreach to rural counties provides free screening and cataract operations, and has been developed by committed ophthalmologists over the past 20 years. Updated data are required on the prevalence of cataract in TAPK in order to further plan and improve eye care services.

This study reports on the results of a population-based survey conducted in 2017, among people 50 years and older. This study aimed to estimate the prevalence

Table 2 Prevalence of cataract by persons on better eye with blindness (BL), severe visual impairment (SVI), moderate visual impairment (MVI) or early visual impairment (EVI)—best corrected visual acuity (BCVA) or pinhole in Tibetan Autonomous Prefecture of Kandze

	Crude			Age adjusted with local population		
	Male	Female	Total	Male	Female	Total
	% 95% CI	% 95% CI	% 95% CI	n† (%) 95% CI	n† (%) 95% CI	n† (%) 95% CI
BL (BCVA <3/60)	0.34 (0.16 to 0.70)	0.82 (0.54 to 1.25)*	0.61 (0.42 to 0.87)	2929 (0.21) (0.08 to 0.60)	1159 (0.69) (0.37 to 1.41)	1767 (0.46) (0.26 to 0.85)
SVI (BCVA>/=3/60 and <6/60)	0.48 (0.26 to 0.89)	1.16 (0.82 to 1.64)*	0.86 (0.63 to 1.17)	1411 (0.32) (0.12 to 0.99)	581 (1.01) (0.54 to 2.05)	828 (0.67) (0.57 to 1.50)
MVI (BCVA>/=6/60 and <6/18)	1.58 (1.13 to 2.22)	3.03 (2.44 to 3.75)**	2.39 (2.00 to 2.87)	7812 (1.15) (0.59 to 2.37)	3715 (2.55) (1.77 to 3.87)	4183 (1.85) (1.33 to 2.66)
EVI (BCVA>/=6/18 and <6/12)	3.79 (3.05 to 4.70)	6.31 (5.45 to 7.30)***	5.21 (4.61 to 5.87)	11 787 (2.76) (1.81 to 4.29)	4397 (5.37) (4.10 to 7.08)	7271 (4.11) (3.27 to 5.20)

*P<0.05, **p<0.01, ***p<0.001.
† Number of people with BL/SVI/MVI/EVI estimated in the study area.

of cataract BL/VI, assess access to services and surgical outcomes. In addition, we aimed to examine eye health equity, by disaggregating study outcomes by sex, ethnic group, altitude and distance to the hospital.

METHODS

The study adhered to the principles of the Declaration of Helsinki. Written informed consent was gained from each study participant before examinations took place. Full data for this study is available on the Rapid Assessment of Avoidable Blindness (RAAB) repository (www.raabdata.info/repository).

Sample size calculation

The expected prevalence of cataract VI (VA<6/18) was 5.2% based on previous studies in Tibetan areas.[23] Assuming 15% precision, 90% response rate and 95% confidence, a sample size of 3279 was required for simple random sampling using the same formula as in the StatCalc module of Epi-Info 6.04D: sample size=Z*Z(P(1P))/D*D (Z=percentile of the standard normal distribution, that is, 1.96 for 95% CI, p=expected prevalence of the condition, D=half the width of the desired sample CI). Earlier studies on cataract BL found a design effect of 1.5 for cluster size 50. The design effect of 1.5 is multiplied the selected sample size (3279) for simple random sampling; a sample size of 4918 was required for this cluster random sampling study.[24] The study teams agreed with 5000 was a good number for publicity. For a cluster size of 50, this resulted in 100 clusters of 50 people aged 50+.

Sampling

Census data were supplied by the local bureau of police for the year of 2010 with projection to 2017. Two-stage sampling was used. First, probability proportionate to size was used to randomly select 100 study villages (clusters), using a list of administration villages as the sampling frame. Second, to select individuals within clusters, compact segment was conducted in the field when the cluster was bigger than the required size.[24] People aged 50+, who had lived in the clusters for over 6 months, were eligible to participate.

Data collection

Data were collected between July and November 2017. The RAAB form was used for data collection.[25] Data were entered in to the RAAB6 software on a daily basis.

Two teams were trained in data collection procedures for 5 days prior to data collection. Each team included an ophthalmologist, an ophthalmic nurse and an assistant. Interobservation variation (IOV) was assessed among the two teams and good agreement was found (Cohen's Kappa=0.8) in VA test and diagnosis of causes of VI.

VA assessment and eye examination

The field teams went door to door in selected segments to test presenting visual acuity (PVA) and pinhole corrected (served as the best corrected visual acuity (BCVA)) for all

eligible study participants. To test PVA and BCVA, a Snellen Tumbling E visual chart was used. All the subjects were requested of case history including surgical and traumatic history and examined with torch on anterior segment including whether an intraocular lenses being implanted, even VA was above 6/12. All eyes with BCVA below 6/12 were assessed for the cause of VI by an ophthalmologist using a torch, portable slit lamp or direct ophthalmoscope with pupil dilatation. Possible causes of VI included refractive error (RE), corneal diseases, lens opacity at the anterior segment and posterior segment diseases.[24] We used BCVA to exclude uncorrected RE as a potential cause for VI as we were interested in cataract VI. Cataract VI was defined as lens opacity at VA levels of <3/60 (BL), ≥3/60 and <6/60 (SVI), ≥6/60 and <6/18 (MVI), ≥6/18 and <6/12 (early visual impairment (EVI)). These definitions were based on the better eye for the person.

Cataract surgical coverage

CSC was calculated as the number of persons operated divided by the total number of people with cataract (any eye at the levels of BL, SVI and MVI), including operated and non-operated persons in a designed geographical area.[26]

Cataract surgery visual outcomes and complications

Participants with postoperated cataract were asked details of the surgery (time, site and cost). Operated eyes with BCVA worse than 6/60 were assessed for possible reasons for the poor outcome. If the participant did not have full sight restored after surgery and another eye disorder causing VI existed in the same eye, the cause of poor outcome was ocular comorbidity. If signs of surgical complications, such as vitreous loss or pupil opacity, were present, the poor outcome was considered to be due to operative complication. Finally, in cases of initial good surgical outcome and subsequent vision loss due to postoperative capsule opacity or retinal detachment, the cause of poor outcome was assigned as long-term complications. If the lens was dislocated and iris tremulousness was found alongside surgical history at home by an unqualified visiting person, this was considered couching. These causes were assigned by the ophthalmologist, using their clinical judgement.

Barriers to cataract surgery

Participants with unoperated cataract were asked about the reasons not having surgery, which were listed on study form as seven options for patient's selection. They were as follows: (1) need not felt; (2) fear for surgery or poor result; (3) cannot afford operation; (4) treatment denied by provider; (5) unaware that treatment is possible; (6) no access to treatment and (7) local reason including transportation, no one accompany to. Patient could select up to two main barriers.[24]

Data analysis

All statistical analyses were performed using a commercially available software package (Stata V.13.1, StataCorp).

Prevalence of VI and BL due to cataract

Crude and age adjusted prevalence and 95% CI of bilateral cataract (better eye) and any eye (including unilateral) were obtained. Results were disaggregated by different levels of BCVA in the better eye, sex, ethnicity (Han, Tibetan, other), and region (arable or pastoral). Logistic regression was used to compare the prevalence of cataract between these groups. A test of proportions was used to determine trends in prevalence by distance to hospital and altitude.

Cataract surgical coverage

CSC was calculated according to different levels of BCVA (by eye and by person). Logistic regression was conducted to examine statistical differences by level of BCVA.

Cataract surgery visual outcomes and complications

Descriptive analysis was conducted to explore age at the time of surgery, place of surgery and surgery type. Results were disaggregated by sex. The distribution of BCVA (≥6/12, ≥6/18 and <6/12, ≥6/60 and <6/18, >6/60) after surgery by surgical type and the site was also explored in descriptive analysis. Similarly, the distribution of presenting VA at these levels in operated eyes by number of years after surgery and causes of poor outcome was presented.

Barriers to cataract surgery

Barriers to cataract surgery were examined by ethnicity and sex by frequency (percentage). Exact logistic regression was conducted for comparisons due to no observations in some groups.

Patient and public involvement statement

Any participants identified as having cataract or other eye diseases were referred to KEC or county hospitals for treatment. The selected villages were sensitised about the study in advance. The head of each village was informed by a formal government document and a phone call from the study ophthalmologist. The village leader informed their community about the study purpose and asked eligible people to wait for the examination team at home. This aimed to maximise study response rates.

RESULTS

Of 5000 people enumerated, 4764 completed the examinations (95.3% response rate). The characteristics of study participants in terms of age, sex, ethnicity, region, distance to hospital and altitude are presented in table 1.

Prevalence of VI and BL due to cataract

The prevalence of bilateral cataract BL (BCVA <3/60 in better eye) was 0.61% (95% CI 0.42 to 0.87), SVI was 0.86% (95% CI 0.63 to 1.17), MVI was 2.4% (95% CI 2.0 to 2.9) and EVI was 5.21% (95% CI 4.61 to 5.87) (table 2). The age-adjusted prevalence of BL was 0.46%, SVI was 0.67%, MVI was 1.85% and EVI was 4.11% (table 2) using

Table 3 Prevalence of cataract by persons with any eye or by total eyes with blindness (BL), severe visual impairment (SVI), moderate visual impairment (MVI) or early visual impairment (EVI)—best corrected visual acuity (BCVA) or pinhole among different groups of people in Tibetan Autonomous Prefecture of Kandze

	Cataract BL BCVA <3/60		Cataract SVI BCVA>/=3/60 and <6/60		Cataract MVI BCVA>/=6/60 and <6/18		Cataract EVI BCVA>/=6/18 and <6/12	
	Persons with any eye % 95% CI	Total eyes % 95% CI	Persons with any eye % 95% CI	Total eyes % 95% CI	Persons with any eye % 95% CI	Total eyes % 95% CI	Persons with any eye % 95% CI	Total eyes % 95% CI
Ethnicity†								
Tibetan	3.88 (3.33 to 4.51)*	2.28 (1.98 to 2.62)*	4.89 (4.28 to 5.60)**	2.91 (2.57 to 3.29)**	7.83 (7.05 to 8.69)**	5.14 (4.68 to 5.63)*	12.3 (11.3 to 13.3)*	8.71 (8.12 to 9.34)
Han	1.82 (0.95 to 3.46)	1.01 (0.54 to 1.87)	2.22 (1.23 to 3.97)	1.41 (0.84 to 2.37)	4.44 (2.94 to 6.66)	3.33 (2.38 to 4.65)	8.89 (6.68 to 11.7)	7.27 (5.81 to 9.07
Other	2.82 (1.06 to 7.29)	1.41 (0.53 to 3.70)	3.52 (1.47 to 8.21)	1.76 (0.73 to 4.17)	7.04 (3.82 to 12.6)	4.23 (2.41 to 7.30)	9.86 (5.91 to 16.0)	7.39 (4.87 to 11.1)
Sex‡								
Male	2.87 (2.24 to 3.69)	1.61 (1.27 to 2.03)	3.74 (3.00 to 4.64)	2.11 (1.71 to 2.59)	5.94 (5.00 to 7.04)	3.76 (3.22 to 4.38)	9.68 (8.48 to 11.0)	6.73 (6.01 to 7.53)
Female	4.22 (3.52 to 5.05)*	2.52 (2.13 to 2.98)**	5.23 (4.45 to 6.14)*	3.19 (2.75 to 3.70)**	8.63 (7.62 to 9.75)***	5.83 (5.23 to 6.49)***	13.5 (12.3 to 14.9)***	9.92 (9.15 to 10.7)***
Region§								
Pastoral area	4.98 (3.84 to 6.43)	2.90 (2.27 to 3.68)	6.43 (5.12 to 8.03)	3.71 (3.00 to 4.58)	10.3 (8.66 to 12.3)	6.52 (5.56 to 7.62)	15.9 (13.9 to 18.2)	11.2 (9.93 to 12.6)
Agriculture area	3.23 (2.69 to 3.87)**	1.89 (1.59 to 2.24)**	4.07 (3.46 to 4.78)**	2.44 (2.10 to 2.83)**	6.72 (5.93 to 7.60)***	4.52 (4.05,5.04)***	10.7 (9.71 to 11.8)***	7.75 (7.14 to 8.40)***
Urban	3.20 (1.53 to 6.56)	1.83 (0.92 to 3.61)	3.20 (1.53 to 6.56)	2.05 (1.07 to 3.90)	4.57 (2.47 to 8.29)	3.20 (1.90 to 5.33)**	9.13 (5.96 to 13.7)	7.31 (5.21 to 10.2)*
Distance from hospital, km¶								
≤200	1.91 (1.33 to 2.74)	1.06 (0.75 to 1.49)	2.44 (1.77 to 3.35)	1.42 (1.05 to 1.91)	4.69 (3.73 to 5.87)	3.10 (2.54 to 3.78)	8.12 (6.84 to 9.61)	6.04 (5.24 to 6.95)
201–400	4.31 (3.38 to 5.50)	2.54 (2.02 to 3.18)	4.94 (3.93 to 6.19)	2.96 (2.40 to 3.64)	7.79 (6.52 to 9.30)	5.08 (4.33 to 5.95)	12.0 (10.4 to 13.8)	8.59 (7.62 to 9.68)
>400	4.53 (3.66 to 5.59)	2.68 (2.20 to 3.26)	6.07 (5.06 to 7.27)	3.61 (3.05 to 4.27)	9.49 (8.23 to 10.9)	6.32 (5.57 to 7.16)	14.9 (13.3 to 16.6)	10.5 (9.58 to 11.6)
P-trend	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Altitude of participants lived m¶								
≤2000	2.10 (1.13 to 3.86)	1.16 (0.64 to 2.07)	2.73 (1.59 to 4.65)	1.68 (1.03 to 2.73)	4.41 (2.89 to 6.67)	3.15 (2.21 to 4.47)	8.19 (6.04 to 11.0)	6.51 (5.11 to 8.27)
2001–3000	2.55 (1.84 to 3.54)	1.46 (1.07 to 1.98)	3.28 (2.46 to 4.37)	1.86 (1.42 to 2.44)	5.40 (4.32 to 6.73)	3.65 (3.01 to 4.42)	9.34 (7.91 to 11.0)	6.71 (5.83 to 7.71)
3001–4000	4.21 (3.48 to 5.08)	2.43 (2.03 to 2.90)	5.31 (4.49 to 6.27)	3.17 (2.71 to 3.69)	8.37 (7.34 to 9.54)	5.54 (4.93 to 6.21)	13.0 (11.7 to 14.3)	9.27 (8.49 to 10.1)
>4000	5.33 (3.63 to 7.77)	3.41 (2.42 to 4.79)	6.40 (4.51 to 9.01)	3.94 (2.87 to 5.40)	11.7 (9.11 to 15.0)	7.25 (5.75 to 9.10)	17.1 (13.9 to 20.7)	11.9 (10.0 to 14.2)
P-trend	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total	3.63 (3.12 to 4.20)	2.12 (1.85 to 2.43)	4.58 (4.00 to 5.21)	2.72 (2.40 to 3.06)	7.45 (6.72 to 8.23)	4.92 (4.50 to 5.38)	11.8 (10.9 to 12.8)	8.52 (7.97 to 9.10)

* P<0.05, **p<0.01, ***p<0.001.
† The prevalence of cataract among Tibetan and other ethnicities was compared with that among Han Chinese.
‡ The prevalence of cataract was compared between male and female.
§The prevalence of cataract in agriculture area and urban was compared with that in pastoral area.
¶The trend test on the prevalence of cataract with different grades of visual acuity across levels of distance from hospital and altitude was performed.

census data supplied by the local bureau of police for the year of 2010 with projection to 2017.

Considering the prevalence of cataract in either eye, the rate of BL was 3.63% (95% CI 3.12 to 4.20), SVI was 4.58% (95% CI 4.00 to 5.21), MVI was 7.45% (95% CI 6.72 to 8.23) and EVI was 11.8% (95% CI 10.9 to 12.8); see table 3. If eyes were counted independently, the prevalence of BL was 2.12% (95% CI 1.85 to 2.43), SVI was

Table 4 Barriers to cataract surgery in sample*, N (%)

	Ethnicity			Sex		
	Tibetan	Han	Other	Male	Female	Total
Unaware treatment is possible	116 (77.3)	16 (84.2)	1 (50.0)	43 (81.1)	90 (76.3)	133 (77.8)
Local reasons†	20 (13.3)	0 (0.00)	0 (0.00)	4 (7.55)	16 (13.6)	20 (11.7)
Need not felt	6 (4.00)	0 (0.00)	1 (50.0)	2 (3.77)	5 (4.24)	7 (4.09)
Treatment denied by provider	5 (3.33)	2 (10.5)	0 (0.00)	2 (3.77)	5 (4.24)	7 (4.09)
Cannot access treatment	4 (2.67)	2 (10.5)	0 (0.00)	3 (5.66)	3 (2.54)	6 (3.51)
Fear	1 (0.67)	1 (5.26)	0 (0.00)	0 (0.00)	2 (1.69)	2 (1.17)
Cost	2 (1.33)	0 (0.00)	0 (0.00)	2 (3.77)	0 (0.00)	2 (1.17)
Total	150	19	2	53	118	171

Barriers are listed by the order of importance on findings from previous studies as instructed in Rapid Assessment of Avoidable Blindness manual. No significant difference was detected by comparing male and female, Han and other two ethnicities.
*Each study subject could select maximum two options listed on the study form.
† Local reason included transportation, no one to accompany to hospital.

2.72% (95%CI 2.41 to 3.06), MVI was 4.92% (95% CI 4.51 to 5.38) and EVI was 8.52% (95% CI 7.98 to 9.10).

Extrapolating these figures to the population of TAPK, the number of people with cataract BL (either eye) was 6680 (95% CI 5741 to 7729), 8428 (95% CI 7361 to 9587) with SVI, 13 709 (95% CI 12 366 to 15 144) with MVI and 21 714 (95% CI 20 058 to 23 554) with EVI. The extrapolated number of eyes with BL was 7802 (95% CI 6809 to 8943), SVI was 10 010 (95% CI 8870 to 11 262), MVI was 18 107 (95% CI 16 598 to 19 800) and EVI was 31 356 (95% CI 29 369 to 33 491).

The prevalence of BL, SVI and MVI due to cataract was higher (p<0.05) among Tibetan compared with Han Chinese (table 3). No significant differences were found between other ethnic minority groups and Han Chinese. The prevalence of cataract VI was higher among women compared with men across all levels of VI (table 3). A significantly lower prevalence of cataract was found in arable areas at all levels of VI compared with pastoral areas. A lower prevalence was also found in urban areas compared with both pastoral and arable areas, but this was only significant for those with VA better than 6/18. Prevalence of cataract VI/BL increased significantly with distance to the health facility and altitude (p<0.05; table 3).

Barriers to cataract surgery

One hundred and seventy-one people with unoperated cataract were interviewed about barriers to cataract surgery. The most common reported barrier to access to cataract operation reported was 'unaware treatment is possible' (77.8%; table 4) followed by inconvenience of transportation and no one to accompany. There was no significant difference detected on barriers to cataract operations by sex or ethnicity.

Cataract surgical coverage

CSC by person increased with severity, from 57.9% (95% CI 51.8 to 63.9) among people with MVI to 82.0% (95% CI 75.2 to 87.6) among people with BL, 77.5% (95% CI 79.7 to 83.3); see table 5. CSC by eyes also increased with severity from 43.8% (95% CI 40.4 to 47.3; MVI) to 64.4% (95% CI: 60.3 to 68.4; BL).

CSC among Tibetans was higher than Han Chinese and other ethnic minority groups in TAPK for people with bilateral cataract and eyes with VA below 6/18. No significant difference in CSC was found at other VA levels.

People with VA worse than 6/18 living in arable (53.5%; 95% CI 46.0 to 60.9) and urban areas (33.3%; 95% CI 7.2 to 76.4) had lower CSC than people in pastoral areas (67.7%; 95% CI 57.5 to 76.5). However, no significant difference was found in CSC by locality if the results were considered by eyes. No significant difference was ascertained for CSC by distance to KEC (by person and by eye). Women in TAPK had much lower CSC by person and eye at all the conditions of BL/SVI/MVI (table 5).

Three hundred and sixty-four cataract operations were received among all the study participants and the majority (68.9%) of these were conducted in patients aged 60–79 years. Approximately two-thirds (66.5%) of the cataract operations were completed in government hospitals and one-third at eye camps (table 6). The operations were predominately completed with intraocular lenses implantation (92.3%). Ten participants (2.75%) operated received couching for cataract in the study area.

Cataract surgery visual outcomes and complications

Of 364 people with cataract extraction (any eye being operated), 216 (71.2%) had VA equal to or better than 6/18, 95 (26.1%) had poor VA outcome (cannot see 6/60; table 7). The main causes of poor outcomes were other oculopathy (60 eyes, 55.6%) and surgical complications (33 eyes, 30.1%; table 8). Late complication was also detected at 13 eyes (12.0%).

Table 5 Cataract surgical coverage (CSC) by eyes and persons (on any eye), % (95% CI)

	CSC (eyes)			CSC (persons)		
	VA <3/60	VA>/=3/60 and <6/60	VA>/=6/60 and <6/18	VA <3/60	VA>/=3/60 and <6/60	VA>/=6/60 and <6/18
Ethnicity†						
Tibetan	64.3 (60.1 to 68.3)	58.5 (54.5 to 62.5)	44.4 (40.9 to 48.0)*	81.6 (74.5 to 87.0)	77.7 (70.7 to 83.3)	59.4 (53.2 to 65.4)
Han	66.7 (48.0 to 81.3)	58.8 (41.6 to 74.1)	37.7 (25.7 to 51.5)	85.7 (37.5 to 98.4)	70.0 (35.7 to 90.7)	38.9 (19.3 to 62.9)
Other	63.6 (32.5 to 86.4)	58.3 (29.6 to 82.3)	36.8 (18.3 to 60.4)	100.0	100.0	50.0 (9.34 to 90.7)
Sex‡						
Male	70.1 (63.7 to 75.7)	64.1 (57.9 to 70.0)	50.0 (44.5 to 55.5)	88.5 (77.6 to 94.5)	85.3 (74.6 to 92.0)	65.3 (55.1 to 74.2)
Female	60.8 (55.5 to 65.8)*	55.0 (50.0 to 60.0)*	40.1 (36.0 to 44.4)**	78.0 (68.7 to 85.1)	72.8 (63.8 to 80.3)	54.0 (46.5 to 61.3)
Region§						
Pastoral area	66.3 (59.3 to 72.7)	60.6 (53.7 to 67.0)	46.7 (40.8 to 52.7)	84.7 (73.0 to 92.0)	83.3 (72.2 to 90.6)	67.7 (57.5 to 76.5)
Agriculture area	64.2 (59.1 to 69.0)*	58.1 (53.2 to 62.9)	42.8 (38.7 to 47.0)	80.8 (71.7 to 87.5)	75.0 (66.1 to 82.2)	53.5 (46.0 to 60.9)*
Urban	46.7 (23.4 to 71.5)	43.8 (21.9 to 68.4)	33.3 (16.5 to 55.9)	66.7 (9.37 to 97.5)	50.0 (9.29 to 90.7)	33.3 (7.17 to 76.4)
Distance from hospital, km						
≤200	73.8 (65.2 to 80.8)	67.7 (59.2 to 75.1)	48.9 (41.7 to 56.1)	90.9 (74.8 to 97.1)	83.8 (67.9 to 92.7)	60.3 (47.2 to 72.2)
201–400	61.6 (54.4 to 68.3)	57.9 (51.0 to 64.6)	44.5 (38.6 to 50.6)	80.7 (68.2 to 89.1)	76.7 (64.2 to 85.8)	59.5 (48.6 to 69.5)
>400	62.1 (56.0 to 67.9)	54.8 (49.0 to 60.5)	41.0 (36.2 to 46.0)	78.9 (67.7 to 86.9)	75.3 (64.9 to 83.4)	55.8 (47.1 to 64.2)
P-trend	0.371	0.229	0.263	0.668	0.735	0.740
Altitude, m						
≤2000	59.3 (39.9 to 76.1)	50.0 (33.1 to 66.9)	34.8 (22.4 to 49.6)	83.3 (31.9 to 98.2)	66.7 (31.3 to 89.8)	40.0 (18.5 to 66.1)
2001–3000	64.9 (55.7 to 73.2)	59.2 (50.3 to 67.5)	42.5 (35.4 to 50.0)	82.1 (63.0 to 92.5)	80.0 (61.5 to 90.9)	48.0 (34.5 to 61.8)
3001–4000	63.6 (58.2 to 68.7)	57.3 (52.1 to 62.3)	43.4 (39.0 to 47.9)	83.2 (74.1 to 89.5)	76.9 (67.9 to 83.9)	58.5 (50.6 to 65.9)
>4000	68.0 (58.2 to 76.4)	64.8 (55.1 to 73.3)	50.0 (41.6 to 58.4)	78.1 (60.2 to 89.4)	80.0 (63.2 to 90.3)	72.3 (57.7 to 83.3)
P-trend	0.750	0.533	0.270	0.897	0.859	0.143
Total	64.4 (60.3 to 68.4)	58.6 (54.6 to 62.5)	43.8 (40.4 to 47.3)	82.0 (75.2 to 87.6)	77.5 (70.7 to 83.3)	57.9 (51.8 to 63.9)

*P<0.05, **p<0.01, ***p<0.001.
†The percentage of CSC among Tibetan and other ethnicities was compared with that among Han Chinese.
‡The percentage of CSC was compared between male and female.
§The percentage of CSC in agriculture area and urban was compared with that in pastoral area.
VA, visual acuity.

Table 6 Age at time of surgery, place of surgery and surgery type in males and females, n (%)

	Male, n (%)	Female, n (%)	Total, n (%)
Age at time of surgery			
40–49	4 (2.56)	12 (5.77)	16 (4.40)
50–59	20 (12.8)	30 (14.4)	50 (13.7)
60–69	45 (28.9)	80 (38.5)	125 (34.3)
70–79	69 (44.2)	57 (27.4)	126 (34.6)
≥80	18 (11.5)	29 (13.9)	47 (12.9)
Place of surgery			
Government hospital	114 (73.1)	128 (61.5)	242 (66.5)
Voluntary/charitable hospital	1 (0.64)	1 (0.48)	2 (0.55)
Private hospital	1 (0.64)	4 (1.92)	5 (1.37)
Eye camp	40 (25.6)	75 (36.1)	115 (31.6)
Surgery type			
Non-IOL	6 (3.85)	12 (5.77)	18 (4.95)
IOL	147 (94.2)	189 (90.9)	336 (92.3)
Couching	3 (1.92)	7 (3.37)	10 (2.75)
Total	156 (100.0)	208 (100.0)	364 (100.0)

IOL, intraocular cataract lenses.

DISCUSSION

This study in TAPK in Sichuan Province, China, established a cataract BL and VI prevalence (at the level of the individual) among people aged 50+ of 0.6% (BL), 0.9% (SVI), 2.4% (MVI) and 5.2% (EVI). Considering the results by eyes, the prevalence was 2.1% (BL), 2.7% (SVI), 4.9% (MVI) and 8.5% (EVI). Extrapolating the prevalence to the total TAPK population aged 50+results in 7802 (BL), 10010 (SVI), 18107 (MVI) and 18107 (EVI) eyes. These numbers indicate the potential workload for cataract services in this study area. The cataract prevalence of 7.5% with VA of worse than 6/18 (any eye) in TAPK is much lower than that found in a 1999 study in other Tibetan areas (13.8%).[17] The prevalence of cataract BL found in our study is also lower than that in neighbouring countries of Pakistan (2004),[27] Nepal (2006)[28] and India (2007)[29] but similar to that in other areas of China (Jiangxi in 2007, Nine-province Study in 2006 and Harbin in 2005).[7 10 30] This likely results from the higher CSR in TAPK, which counteracted the higher prevalence of cataract[16] compared with other rural areas in China.[10]

Tibetan people and people living in pastoral areas had a much higher prevalence of cataract BL/VI. This may be caused by the greater exposure to sunlight. Herdsmen and their families mobilise frequently and spend more time outdoors. We detected significant higher CSC for eyes with MVI, not for person, nor at the other BL/VI levels, among Tibetan people compared with Han Chinese. There was a higher prevalence of cataract VI and lower CSC in women, compared with men, which contrasts studies from other areas China.[7 10] However, it is consistent with results from previous eye studies in Tibet and neighbouring countries.[16 17 27 29] This suggests that planning future cataract services will need to ensure that Tibetan people, herdsmen and women are included.

The prevalence of cataract VI increased by distance to the hospital (KEC), which is located in a lower base of TAPK. Geographically, the distance increased with altitude levels in TAPK. The higher prevalence of cataract found at high altitude levels may be due to greater levels of ultraviolet light exposure in these areas,[12–15] as there were no CSC difference found among distance levels.

The general CSC for BL (64.4% by eye and 82.0% by person) in TAPK was higher than that in other parts of China.[7 17 18] This could be attributed to the effectiveness of the mobilised eye care model in TAPK. The lower CSC detected by person with VA of 6/18 in arable areas compared with that in pastoral areas was likely due to the subsidised outreach services being strengthened in the pastoral areas. This reminds that the same service is also needed in arable areas in TAPK.

Our study found that women had a higher prevalence of cataract and lower CSC compared with men in TAPK. This is consistent with a previous study conducted in other

Table 7 Cataract surgical outcomes in sample with available correction (best corrected visual acuity), n (%)

	Surgery type			Surgery site				Total
	Non-IOL	IOL	Couching	Public hospital	Charity hospital	Private hospital	Temporary place	
Very good: can see 6/12	0 (0.00)	173 (51.5)	0 (0.00)	133 (55.0)	1 (50.0)	2 (40.0)	37 (32.2)	173 (47.5)
Good: can see 6/18	0 (0.00)	43 (12.8)	0 (0.00)	29 (12.0)	0 (0.00)	0 (0.00)	14 (12.2)	43 (11.8)
Borderline: can see 6/60	3 (16.7)	49 (14.6)	1 (10.0)	36 (14.9)	1 (50.0)	0 (0.00)	16 (13.9)	53 (14.6)
Poor: cannot see 6/60	15 (83.3)	71 (21.1)	9 (90.0)	44 (18.2)	0 (0.00)	3 (60.0)	48 (41.7)	95 (26.1)
Total	18 (100.0)	336 (100.0)	10 (100.0)	242 (100.0)	2 (100.0)	5 (100.0)	115 (100.0)	364 (100.0)

IOL, intraocular cataract lenses.

Table 8 Visual acuity (VA) in operated eyes in sample by years after surgery (presenting VA) and causes of poor outcome

	Years after surgery, n (%)			Cause of borderline and poor presenting VA, n (%)					
	≤3 years	4–6 years	≥7 years	Suffering from other oculopathy	Surgical complications	Refractive error	Late complication	Not applicable, can see 0.5	Total, n (%)
Very good: can see 6/12	69 (44.8)	38 (36.9)	29 (27.1)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	136 (100.0)	136 (37.4)
Good: can see 6/18	25 (16.2)	21 (20.4)	16 (15.0)	16 (16.0)	12 (20.0)	29 (74.4)	5 (17.2)	0 (0.00)	62 (17.0)
Borderline: can see 6/60	30 (19.5)	16 (15.5)	12 (11.2)	24 (24.0)	15 (25.0)	8 (20.5)	11 (37.9)	0 (0.00)	58 (15.9)
Poor: cannot see 6/60	30 (19.5)	28 (27.2)	50 (46.7)	60 (60.0)	33 (55.0)	2 (5.13)	13 (44.8)	0 (0.00)	108 (29.7)
Total	154 (100.0)	103 (100.0)	107 (100.0)	100 (100.0)	60 (100.0)	39 (100.0)	29 (100.0)	136 (100.0)	364 (100.0)

Tibetan areas.[17] However, nowadays in many other areas of China, there is no difference in cataract service indicators by sex. Local eye care staff explained that women in this Tibetan area spend more time on the farm and caring for the family which limits their opportunities to travel to health facilities. This may explain the difference in prevalence found. This highlights that future eye care efforts should target disadvantaged women in TAPK and possibly in other Tibetan areas. Couching for cataract is regarded as malpractice in China. This study still found 10 people who received couching at home. This suggests that improvement is needed to improve awareness and identify cataract early.

The quality of cataract surgery, as measured by cataract surgical outcomes in TAPK, was better than that in other parts of China.[6 18 20] However, the proportion of good surgical outcome (postoperated VA is better than 6/18) is still lower than WHO recommendations, which is, with available correction, 80% of the operated eyes can see 6/18. Over 40% of the cataract operations completed in outreach resulted in 'cannot see 6/60', with surgical complications noted in a high proportion of those with poor outcomes. This highlights the urgent need for further training of cataract surgeons, and regular monitoring of cataract surgical outcomes in order to improve the quality of the surgeries, particularly in eye camps.

The most commonly cited barrier to cataract surgery was 'unaware treatment is possible' which suggests that health education may improve uptake of services and should be added to the outreach activities. Patients who have benefited from surgery could also promote cataract services in their communities. Compared with many other areas in China where free outreach eye services (2007 in Jiangxi and 2015 in Xinjiang)[7 18] are not available, the barriers of 'cannot access treatment' and 'cost' were less common in TAPK. This could imply that the long-term outreach free eye services in TAPK has had an impact on reducing these barriers.

This study has some limitations that should be taken into account when interpreting the results. The sample of this study was randomly selected from the census sample frame. However, in practice, we noticed that a lower proportion of Han Chinese were selected (data not presented) compared with the general population in TAPK, which may lead to selection bias. Different findings between Han Chinese and Tibetan were discussed above; however, no significant difference was detected in the prevalence of cataract VI, barriers to cataract operations and CSC between Han Chinese and other ethnicities. TAPK has similar diversities to the rest of other Tibetan areas in China and allows comparisons to be made to these areas; however, results may not be comparable or generalisable to other parts of China. Finally, the process of understanding barriers to cataract surgery was brief (single question with seven response options), and therefore we may not have captured the whole spectrum of possible barriers in this population.

This study also has several strengths. The RAAB survey methodology, a recognised survey tool, was followed to conduct the survey. Trained local study teams led by an ophthalmologist collected data. An IOV study was conducted, which found high Kappa agreement between the ophthalmologists in eye examination and diagnosis. This meant that data collection across the two teams was consistent. Simple study tools were used. A door-to-door sampling, and rigorous sensitisation was conducted prior to the study, which enabled high response rates to be achieved.

CONCLUSION

The study detected a low prevalence of VI and BL due to cataract in TAPK in Sichuan Province. This prevalence was similar to other rural parts of China. Women had higher prevalence of cataract and lower CSC although an overall high CSC was found in this area compared with the other areas in China. Outcomes from cataract surgery were poor for 26.1% of people with previous surgery, suggesting improvements in surgical training and monitoring of surgical outcomes are required.

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