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# Real-world visual outcomes of cataract surgery based on population-based studies: a systematic review

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## ABSTRACT

**Background/aims** Quantity of cataract surgery has long been an important public health indicator to assess health accessibility, however the quality of care has been less investigated. We aimed to summarise the up-to-date evidences to assess the real-world visual outcomes after cataract surgery in different settings.

**Methods** A systematic review was undertaken in October 2021. Population-based cross-sectional and longitudinal studies reporting vision-related outcomes after cataract surgery published from 2006 onward were included. A meta-analysis was not planned.

**Results** Twenty-six cross-sectional studies from low-income and middle-income countries (LMICs) and five cross-sectional studies from high-income countries (HICs) were included. The proportions of participants with postoperative presenting visual acuity (VA)  $\geq 0.32$  (20/60) were all over 70% in all HICS studies, but mostly below 70% in LMICS studies, ranging from 29.9% to 80.5%. Significant difference in postoperative VA was also observed within countries. The leading causes for postoperative visual impairment (defined mostly as presenting VA  $< 20/60$ ) mainly included refractive error, ocular comorbidities and surgical complications including posterior capsule opacification, except for one study in Nigeria wherein the leading cause was aphakia. Only four population-based cohort studies were included with 5–20 years of follow-up time, generally demonstrating no significant changes in postoperative visual outcomes during the follow-up.

**Conclusions** We observed large inequality in the visual outcomes and principal causes of visual impairment after cataract surgery among different countries and regions. Structured quality control and enhancement programmes are needed to improve the outcomes of cataract surgery and reduce inequality.

## INTRODUCTION

Cataract surgery is the most commonly performed elective surgery worldwide, with more than 20 million surgeries performed annually.<sup>1–2</sup> According to the latest Global Burden of Disease study, cataract remains the leading cause of global blindness, meanwhile increasing numbers of cataract surgery are being performed to reduce the ‘backlog’ of cataract blindness in the ageing society.<sup>3–5</sup> The cataract surgical rate, which represents the number of surgeries performed per million population in a given year, is the most important public health parameter to assess accessibility to cataract service.<sup>6</sup> In parallel with several important advances that have taken place during the last decades, including

## Key questions

### What is already known on this topic?

⇒ Cataract remains the leading cause of global blindness. The quantity of cataract surgery keeps increasing in recent decades, but the quality of cataract surgery could vary remarkably.

### What this study adds?

⇒ Based on a systematic review of all population-based studies reporting vision-related outcomes after cataract surgery published in the past 15 years, we identified substantial differences in the type of cataract surgery, postoperative vision as well as causes for postoperative visual impairment within and among different countries and regions. The reported postoperative visual outcomes were generally less ideal compared with the WHO recommendation, especially in low-income and middle-income countries. There is a paucity of population-based data from many countries worldwide, and also scarce data from long-term cohorts.

### How this study might affect research, practice or policy?

⇒ More attention should be paid to understand and improve the quality of cataract surgery and minimise global inequality in the contemporary era.

the micro-incision cataract surgical technique, newer generations of intraocular lens (IOL) and IOL calculation formulas, more attention is being paid to maximise the benefit that patient could achieve through cataract surgery.<sup>7</sup>

In addition to accessibility, the quality of care plays a critical role towards universal health coverage.<sup>8</sup> Despite being proved as one of the most cost-effective health interventions, cataract surgery can be associated with poor visual outcomes due to surgical complications, ocular comorbidities or inadequate optical correction despite the use of an IOL.<sup>9–10</sup> The postoperative visual acuity (VA) is a simple direct parameter which could reflect the quality of cataract surgery and postsurgical care to a large extent. The Global Initiative for the Elimination of Avoidable Blindness indicates that cataract surgical services should have a high success rate in terms of VA and improved quality of life.<sup>11</sup>



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Therefore, understanding the nowadays visual outcomes of cataract surgery in the real world is crucial in formulating future strategies on the cataract management, providing important reference for both ophthalmologists and decision-makers.

Both the quantity and quality of cataract surgery vary markedly among different countries and even within countries due to differences in socioeconomic status, availability of medical resources and clinical practice patterns.<sup>12 13</sup> The purpose of this review was to summarise the visual status of participants after cataract surgery based on representative population-based studies in both high-income countries (HICs) and low-income and middle-income countries (LMICs), as well as the main cause for visual impairment (VI) after cataract surgery.

## METHODS

The protocol of this systematic review was prospectively registered at PROSPERO (CRD42021292087). The reporting of this systematic review is based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 checklist.

### Eligibility criteria for considering studies for this review

We included population-based studies reporting vision-related outcomes after cataract surgery. Only full-text original studies published in English were included. Unpublished studies and meeting abstracts were not included due to uncertainty of methodological quality. Studies evaluating cataract surgical outcomes other than VA were further excluded.

### Search methods for identifying studies

Two researchers (XH and JZ) independently searched PubMed, Embase and Google Scholar from 1 January 2006 to 15 November 2021. The keywords included 'cataract surgery', 'cataract extraction', 'population-based', 'outcome', 'visual acuity' and 'vision'. Detailed search terms could be found in the online supplemental appendix 1. Reference lists in published articles were also reviewed.

### Study selection

To identify relevant studies, retrieved articles were exported to Endnote (V.X9, Clarivate Analytics). After removing duplicates from the initial search, the titles and abstracts of the articles were screened by JZ and XH, independently. Full-text screening was performed subsequently to further exclude articles that did not meet the inclusion criteria. In case of discrepancies, the results were conferred with a third investigator (ZL). For periodical cross-sectional studies, such as the China Nine-Province Survey, the report with larger sample size and published more recently was selected.

### Data collection and risk of bias assessment

Data were extracted and entered into an Excel spreadsheet (Microsoft, Redmond, Washington, USA) with predetermined headings including first author, year of publication, study design, country, number of participants, age, gender, examination time, type of cataract surgery, postoperative presenting VA (PVA), postoperative best-corrected VA (BCVA), causes of postoperative VI and so on. For cohort studies which included multiple follow-up visits, the examination time, number of participants, type of cataract surgery, postoperative PVA and BCVA and causes of postoperative VI were recorded separately for each study visit.

We assessed the quality of evidence using the Newcastle-Ottawa Scale (NOS) and adapted NOS for cohort and cross-sectional

studies, respectively.<sup>14</sup> This tool evaluated three bias domains, including selection, comparability and outcome. Two investigators (JZ and XH) independently assessed the risk of bias, and discrepancies were resolved through discussion (tables 1–3; online supplemental table 1).

### Data synthesis and analysis

Categorising each study site into LMICs or HICs was based on the World Bank list of economies.<sup>15</sup> The VA representation format varied among the included studies, and equivalent Snellen decimal VA was presented to facilitate direct comparison and understanding.

Given the aim of this review was to present and compare visual outcomes of cataract surgery, findings were reported narratively and meta-analysis was not planned. Ethical approval was not required for this study.

## RESULTS

We identified 687 studies after a systematic literature review. After checking for duplicates and eligibility criteria, 652 studies were further excluded, including 93 duplicates, 386 studies due to irrelevant topics, 133 studies without population-based design and 32 studies written in language other than English. Forty-three full-text articles were screened, and eight studies were further excluded due to a lack of data on postoperative VA status. No study was excluded based on further quality appraisal. As a result, this review included 35 population-based studies which reported the visual outcome of cataract surgery (figure 1).

The included studies differed with respect to the study type, country, year as well as the definition and categorisation of postoperative VA and VI. A total of 31 population-based cross-sectional studies were included, among which 26 (83.87%) were conducted in LMICs,<sup>16–41</sup> and only 5 (16.13%) were conducted in HICs (tables 1 and 2).<sup>42–46</sup> An additional four population-based cohort studies were identified, including two from China,<sup>47 48</sup> one from Australia<sup>49</sup> and one from Sweden<sup>50–53</sup> (table 3). Notably, the American Academy of Ophthalmology Intelligent Research In Sight (IRIS) study<sup>46</sup> was classified as a cross-sectional study in this review, given that it only reported the VA at one visit within 90 days after cataract surgery. All included studies displayed no significant bias.

In assessing the postoperative VA outcomes, most available studies included middle-aged and elderly population and reported the proportion of participants with PVA and BCVA in different VA subgroups (mostly including the  $\geq 0.32$  group). Table 1 demonstrates the detailed visual outcomes of cataract surgery for each study in time sequence. Of the 26 population-based cross-sectional studies in LMICs, half were from China ( $n=7$ )<sup>28 30 35 37 39–41</sup> and India ( $n=6$ ).<sup>18 20 24 27 33 34</sup> Six studies in China included subjects aged  $\geq 50$  years with sample size ranging from 3484 to 51 310, and the proportions of participants with postoperative PVA  $\geq 0.32$  (recorded as 6/18 or 20/60 or 20/63) ranged from 44.5% (Shen *et al* 2020 Southwestern China)<sup>41</sup> to 73.5% (Zhang *et al* 2018 Northern China).<sup>37</sup> The proportions of participants with postoperative BCVA  $\geq 0.32$  ranged from 59.3% (Jiachu *et al* 2019 Tibetan China)<sup>39</sup> to 81.0% (Li *et al* 2014 Northern China).<sup>30</sup> Postoperative VI was mostly defined as PVA  $< 0.32$ , ocular comorbidities were the leading cause of postoperative VI. The other study in Heilongjiang, Northern China (2014)<sup>30</sup> included 10 384 participants aged 1–94 years and only 21 received cataract surgery (intracapsular cataract extraction [ICCE]/extracapsular cataract extraction [ECCE]). In this study, 57.1% participants achieved postoperative PVA

**Table 1** Visual outcomes of cataract surgery in population-based cross-sectional studies in low-income and middle-income countries

First author	Year	Region	Participants	Age (years)	Gender (F/M)	Patients/eyes*	Examination time	Type of cataract surgery	Duration since cataract surgery	Postoperative PVA	Postoperative BCVA	Causes of visual impairment
Bourne <i>et al</i> <sup>18</sup>	2007	Pakistan	16 507	≥30	8766/7741	1317/1788	2002–2003	ICCE: 61.0% ECCE: 34.0%	≤3 years: 49.1% 4–8 years: 31.3% ≥9 years: 19.6%	≤6/12: 15.4% <6/12–6/18: 14.1% <6/18–6/60: 35.3% <6/60–3/60: 4.80% <3/60: 18.7%	≤6/12: 31.5% <6/12–6/18: 18.6% <6/18–6/60: 27.5% <6/60–3/60: 3.40% <3/60: 29.5%	Def: PVA <6/12 RE: 53.4% Comorbidities: 23.5% Complications: 21.4%
Lindfield <i>et al</i> <sup>17</sup>	2008	Sakhira District, Bangladesh	3503	≥50	1834/1669	1702/13	2005	–	>5 years: 42.3% <5 years: 57.7%	≥6/18: 60.1% <6/18–6/60: 16.4% <6/60: 23.5%	≥6/18: 67.6% <6/18–6/60: 12.2% <6/60: 20.2%	Def: VA <6/18 Comorbidities: 33.8% Complications: 30.6% RE: 25.8% PCO: 9.70%
Salomão <i>et al</i> <sup>19</sup>	2009	São Paulo, Brazil	3642	≥50	2115/1527	231/957	2004–2005	Phaco: 45.4% ECCE: 50.4% ICCE: 3.90%	>10 years: 22.1% 5–10 years: 25.5% ≤5 years: 52.4%	>20/40: 41.2% ≤20/40–20/63: 28.1% <20/63–20/200: 14.2% <20/200–20/400: 6.30% <20/400: 10.2%	>20/40: 61.9% ≤20/40–20/63: 17.6% <20/63–20/200: 8.20% <20/200–20/400: 5.10% <20/400: 7.10%	Def: PVA <20/63 Comorbidities: 68.8% RE: 16.5% PCO: 4.60%
Murthy <i>et al</i> <sup>18</sup>	2009	Gujarat, India	4738	≥50	2585/2153	834/1299	2007	ICCE: 6.60% ECCE: 8.60% ECCE+IOL: 16.8% Phaco+IOL: 12.2% MSICS+IOL: 55.1%	≥10 years: 17.5% 6–10 years: 15.7% 3–5 years: 35.3% ≤2 years: 30.8%	≥20/32: 18.7% 20/40–20/63: 32.0% <20/63–20/200: 31.3% <20/200–20/400: 2.50% <20/400: 15.5%	≥20/32: 55.7% <20/40–20/63: 18.8% <20/63–20/200: 14.5% <20/200–20/400: 1.20% <20/400: 9.80%	Def: PVA <20/40 RE: 45.5% Comorbidities: 26.9% PCO: 16.5%
Kandel <i>et al</i> <sup>1</sup>	2010	Nepal	5138	≥50	2701/2437	359/485	2006	ICCE/ECCE	≥3 years: 59.0%	≥6/18: 61.4%	≥6/18: 84.7%	Def: PVA <6/18 RE: 54.2% Comorbidities: 22.0% PCO: 8.00%
Vijaya <i>et al</i> <sup>20</sup>	2010	South India	9600	≥40	–	934/1385	2003	–	>3 years: 41.8% <3 years: 57.8%	20/20: 6.20% 20/25–20/60: 47.5% <20/60: 45.3% <20/200: 21.1% <20/400: 16.8%	20/20: 19.7% 20/25–20/60: 57.9% <20/60: 21.4% <20/200: 12.4% <20/400: 9.70%	Def: PVA <20/60 RE: 52.5% Comorbidities: 30.2% PCO: 7.90%
Imam <i>et al</i> <sup>25</sup>	2011	Nigeria	13 591	≥40	6560/7031	217/288	2005–2007	–	–	≥6/18: 29.9% <6/18–6/60: 26% <6/60: 44.1%	≥6/18: 55.9% <6/18–6/60: 20.8% <6/60: 23.5%	Def: PVA <6/18 Aphakia: 38.6% Comorbidities: 24.4% Complications: 18.8% RE: 10.9% PCO: 3.00%
Nangia <i>et al</i> <sup>24</sup>	2011	Rural Central India	4711	≥30	–	234/318	2006	–	–	≥6/12: 25.0% <6/12–6/18: 12.0% <6/18–6/60: 52.0% <6/60: 11.0%	≥6/12: 53.0% <6/12–6/18: 10.0% <6/18–6/60: 26.0% <6/60: 10.0%	Def: PVA <6/18 RE: 41.8% Comorbidities: 14.9% PCO: 13.9% Complications: 12.4%
Thapa <i>et al</i> <sup>23</sup>	2011	Bhaktapur District, Nepal	4003	≥40	–	151/226	2001	–	≥5 years: 58.9% <5 years: 41.1%	≥6/18: 54.4% <6/18–6/60: 34.5% <6/60: 11.1%	≥6/18: 72.6% <6/18–6/60: 19.0% <6/60: 8.40%	Def: BCVA <6/18 Comorbidities: 54.8% Complications: 27.4% PCO: 14.5%
Brian <i>et al</i> <sup>22</sup>	2011	Fiji	1381	≥40	–	88/113	2009	ICCE: 14.3% ECCE: 85.7%	–	*ECCE eyes ≥6/18: 56.6% <6/60: 19.7% NLP: 2.60%	–	–
Khanna <i>et al</i> <sup>27</sup>	2012	Andhra Pradesh, India	7281	≥50	–	1124/1548	2009	–	>10 years: 6.30% 5–10 years: 30.1% <5 years: 63.6%	<6/18: 31.8%	<6/18: 19.3%	Def: PVA <6/18 RE: 38.8% Comorbidities: 30.3% Complications: 15.9% Aphakia: 15.0%
Odujibo <i>et al</i> <sup>26</sup>	2012	Plateau State, Nigeria	4115	≥50	2176/1939	119/180	2007	–	>5 years: 45.0% <5 years: 55.0%	≥6/18: 25.6% <6/18–6/60: 16.1% <6/60: 58.3%	–	Def: PVA <6/60 Aphakia: 65.1% Comorbidities: 20.9% Complications: 14.0%
Li <i>et al</i> <sup>28</sup>	2013	Hainan, South China	6482	≥50	3471/3011	–/524	2010	–	>6/18: 59.4% <6/18–6/60: 20.0% <6/60: 20.6%	–	–	Def: PVA <6/18 Comorbidities: 35.4% RE: 32.5% Complications: 32.0%

Continued

**Table 1** Continued

First author	Year	Region	Participants	Age (years)	Gender (F/M)	Patients/eyes*	Examination time	Type of cataract surgery	Duration since cataract surgery	Postoperative PVA	Postoperative BCVA	Causes of visual impairment	
Li <i>et al</i> <sup>10</sup>	2014	Heilongjiang, North China	10384	1–94	–	21/21	2008–2009	ICCE/ECCE	<5 years: 66.0% <10 years: 81.0%	≥20/60: 57.1% <20/400–20/60: 19.1% <20/400: 23.8%	≥20/60: 81.0%	Def: PVA <20/60 RE: 33.0% Complications: 25.0% Comorbidities: 17.0% PCO: 8.00%	
Katibeh <i>et al</i> <sup>25</sup>	2014	Varamin Iran	2819	≥50	–	341/526	2009	–	–	≥6/18: 71.9% <6/18–6/60: 13.5% <6/60: 14.6%	–	Def: PVA <6/18 Comorbidities: 42.6% Complications: 33.8% RE: 25.0%	
Mörchen <i>et al</i> <sup>21</sup>	2015	Takeo Province, Cambodia	4471	≥50	2933/1538	–/372	2011–2012	–	≤5 years: 33.3% >5 years: 66.7%	≥6/18: 69.9% <6/18–6/60: 16.9% <6/60: 13.2%	–	Def: PVA <6/60 Comorbidities: 62.5% Complications: 12.5% RE: 6.30%	
Pawitroedjo <i>et al</i> <sup>22</sup>	2016	Suriname	2998	≥50	–	1003/1003	2013–2014	–	3 years: 51.3% 4–6 years: 20.7% >7 years: 27.9%	≥6/18: 80.5% <6/18–6/60: 9.80% <6/60: 9.80%	–	Def: PVA <6/60 Comorbidities: 52.0% RE: 30.0% Complications: 11.0%	
Marmamula <i>et al</i> <sup>24</sup>	2016	South Indian State of Andhra Pradesh	7378	≥40	3957/3421	870/1228	2011–2012	–	<5 years: 65% 6–10 years: 23.3% >10 years: 11.7%	≥6/18: 74.6% <6/18–6/60: 12.5% <6/60: 13.0%	–	Def: PVA <6/18 Comorbidities: 30.5% RE: 28.7% Complications: 21.1% Aphakia: 18.4%	
Paul <i>et al</i> <sup>23</sup>	2016	South India	5530	≥50	–	749/1112	2010	MICS: 74.7% ECCE: 12.5% ICCE: 8.50% Phaco: 2.90%	1–2 years: 26.5% 3 years: 18.0% 4–10 years: 44.3% >10 years: 11.1%	≥6/18: 53.1% <6/18–6/60: 38.1% <6/60: 8.80%	–	Def: PVA <6/18 RE: 44.6% Comorbidities: 27.2% PCO: 14.2% Complications: 3.64%	
Zhang <i>et al</i> <sup>25</sup>	2017	Chaonan, Guangdong, Southern China	3484	≥50	2087/1397	155/211	2012	–	–	≥6/18: 67.2% <6/18–6/60: 16.1% <6/60–3/60: 4.30% <3/60: 12.3%	–	Def: PVA <6/18 Comorbidities: 42.0% Complications: 33.3% RE: 24.6%	
Zhang <i>et al</i> <sup>27</sup>	2018	Hohhot, North China	3985	≥50	2281/1704	131/189	2014	–	–	≥6/12: 58.7% <6/12–6/18: 14.8% <6/18–6/60: 11.1% <6/60: 15.4%	–	–	
Thoufeeq <i>et al</i> <sup>16</sup>	2018	Maldives	3020	≥50	1787/1233	850/850	2014	–	–	≥6/18: 67.9% <6/18–6/60: 17.3% <6/60: 14.8%	≥6/18: 76.6% <6/18–6/60: 10.0% <6/60: 13.4%	–	–
Zhao <i>et al</i> <sup>40</sup>	2018	China	51310	≥50	29065/22245	21002/877	2014	–	–	≥20/32: 32.4% <20/40–20/63: 29.9% <20/63–20/200: 20.6% <20/200: 17.2%	≥20/32: 54.7% <20/40–20/63: 20.5% <20/63–20/200: 11.7% <20/200: 13.1%	–	–
Jiandu <i>et al</i> <sup>19</sup>	2019	Tibetan, China	4764	≥50	2677/2087	364/364	2017	–	≤3 years: 42.3% 4–6 years: 28.3% ≥7 years: 29.4%	–	≥6/12: 47.5% <6/18–6/12: 11.8% <6/10–6/18: 14.6% <6/60: 26.1%	Def: PVA <6/18 Comorbidities: 51.3% Complications: 34.8% RE: 6.10%	
Watanabe <i>et al</i> <sup>18</sup>	2019	Parintins, Brazil	2041	≥45	1041/1000	176/275	2014–2015	Phaco: 62.9% ECCE: 35.3% Unclear: 1.80%	–	≥20/32: 44.4% <20/40–20/63: 20.8% <20/63–20/200: 14.4% <20/200–20/400: 2.60% <20/400: 15.9%	≥20/32: 59.2% <20/40–20/63: 13.0% <20/63–20/200: 10.4% <20/200–20/400: 1.50% <20/400: 15.9%	Def: PVA <20/32 Comorbidities: 34.8% Complications: 33.3% RE: 26.6%	
Shen <i>et al</i> <sup>11</sup>	2020	Southwestern (Yunnan), China	6546	≥50	3943/2603	395/525	2010	–	≤10 years: 84.0% >10 years: 14.3%	≥20/32: 24.6% <20/40–20/63: 29.3% <20/63–20/200: 30.9% <20/200: 24.6%	≥20/32: 24.6% <20/40–20/63: 37.3% <20/63–20/200: 29.9% <20/200: 14.9%	Def: PVA/BCVA <20/63 Comorbidities: 50.8% PCO: 25.1% RE: 22.7%	

\*Participants or eyes that received cataract surgery. BCVA, best-corrected visual acuity; Def, definition of visual impairment; ECCE, extracapsular cataract extraction; ICCE, intracapsular cataract extraction; IOL, intraocular lens; MICS, manual small incision cataract surgery; PCO, posterior capsule opacification; PVA, presenting visual acuity; RE, refractive error.

**Table 2** Outcomes of cataract surgery in population-based cross-sectional studies in high-income countries

First author	Year	Region	Participants	Age (years)	Gender (F/M)	Patients/eyes*	Examination time	Duration since cataract surgery	Postoperative PVA	Postoperative BCVA	Causes of visual impairment
Barañano <i>et al</i> <sup>42</sup>	2008	California	6357	≥40	3687/2670	261/422	2000–2003	–	>20/40: 51.9% ≤20/40–20/63: 22.8% ≤20/80–20/160: 9.00% ≤20/200: 16.4%	>20/40: 67.8% ≤20/40–20/63: 13.5% ≤20/80–20/160: 6.20% ≤20/200: 12.6%	Def: PVA <20/40 comorbidities: 50.7% RE: 33.0% PCO: 7.40%
Lavanya <i>et al</i> <sup>45</sup>	2009	Singapore	3266	40–80	1657/1568	438/592	2004–2006	–	≤20/60: 26.8%	≤20/60: 10.8%	Def: PVA ≤20/60 RE: 59.5% Comorbidities: 33.6% PCO: 6.00%
Gupta <i>et al</i> <sup>43</sup>	2013	Singapore	3388	≥40	–	486/795	2007–2009	–	≤20/60: 25.5%	≤20/60: 10.9%	Def: PVA ≤20/60 RE: 57.1% Comorbidities: 31.6% PCO: 7.90%
Keel <i>et al</i> <sup>44</sup>	2018	Australia	4836	≥40	–	773/1333	2015–2016	47.6%: ≤3 years 43.7%: >3 years	≥6/12: 77.6% <6/12–6/60: 19.7% <6/60: 2.63%	–	Def: PVA <6/12 Comorbidities: 50.0% RE: 37.6% surgery Complications: 0.30%
Owen <i>et al</i> <sup>46</sup>	2021	USA	68 526 828	–	–	1 824 196/3 648 392	2019–2020	Within 90 days	≥20/20: 28.8%	≥20/20: 83.0%	–

\* Participants or eyes received cataract surgery.  
BCVA, best-corrected visual acuity; Def, definition of visual impairment; IOL, intraocular lens; PCO, posterior capsule opacification; PVA, presenting visual acuity; RE, refractive error.

**Table 3** Outcomes of cataract surgery in population-based cohort studies

Cohort	Study location	Baseline year	Participants	Age (years)	Gender (F/M)	Examination time	Patients/eyes*	Type of cataract surgery	Duration since cataract surgery	Postoperative PVA	Postoperative BCVA	Causes of visual impairment
The Beijing Eye Study <sup>47</sup>	Beijing, China	2001	4378	≥40	2458/1920	2006 (5 years)	92/133	–	≤3 years: 42.1% >3 years: 57.9%	≥6/12: 72.9% <6/12–6/18: 6.80% <6/18–6/60: 13.5% <6/60: 6.80%	≥6/12: 88.0% <6/12–6/18: 1.50% <6/18–6/60: 8.30% <6/60: 2.30%	Def: PVA <6/18 RE: 50.0% Comorbidities: 38.3% PCO: 7.70%
The Blue Mountains Eye Study <sup>49</sup>	Sydney, Australia	1992–1994	3654	≥49	2072/1582	1997–1999 (5 years)	–	–	–	<6/12: 26.0%	<6/12: 8.60%	Def: PVA <6/12 RE: 66.7% Comorbidities: 9.10%
						2002–2004 (10 years)	90/130	–	–	<6/12: 23.0%	<6/12: 9.20%	Def: PVA <6/12 RE: 59.3% PCO: 18.5% Comorbidities: 14.8%
The Liwan Eye study <sup>48</sup>	Guangzhou, China	2003–2004	1405	≥50	–	2003–2004	62/90	Phaco: 54.4% ECCE: 44.4% ICCE: 1.2%	>10 years: 16.7% ≤10 years: 83.3%	* PVA with pinhole ≥6/18: 62.2% <6/18–6/60: 22.2% <6/60–3/60: 3.3% <3/60: 12.2%	≥6/18: 75.6% <6/18–6/60: 13.3% <6/60–3/60: 2.20% <3/60: 8.90%	Def: PVA <6/18 Comorbidities: 50.0% Uncorrected aphakia: 20.6% RE: 14.7% PCO: 14.7%
						2009 (5 years)	44/62	Phaco: 100%	–	≥6/18: 59.7% <6/18–6/60: 17.7% <6/60–3/60: 14.5% <3/60: 8.06%	≥6/18: 80.6% <6/18–6/60: 9.68% <6/60–3/60: 8.06% <3/60: 1.61%	Def: PVA ≤6/18 RE: 42.8% Comorbidities: 35.7% PCO: 7.10%
Sweden cohort <sup>50–53</sup>	Sweden	1997–1998	863	≥30	578/312	2002–2003 (5 years)	810/810	Phaco: 97.9	–	–	≤20/40: 16.4%	–
						2007–2008 (10 years)	289/-	Phaco: 100%	–	–	≥20/30: 65.0% 20/40–20/32: 11.0% 20/42–20/80: 9.0% 20/100–20/200: 5.00% <20/200: 9.00%	–
						2012–2013 (15 years)	168/168	Phaco: 100%	–	–	≥20/30: 71.0% 20/40–20/32: 10.0% 20/42–20/80: 6.00% 20/100–20/200: 5.00% <20/200: 8.00%	–
						2017–2018 (20 years)	114/-	Phaco: 100%	–	–	Median: 20/63	–

\*Participants or eyes received cataract surgery. BCVA, best-corrected visual acuity; Def, definition of visual impairment; ECCE, extracapsular cataract extraction; ICCE, intracapsular cataract extraction; PCO, posterior capsule opacification; PVA, presenting visual acuity; RE, refractive error;

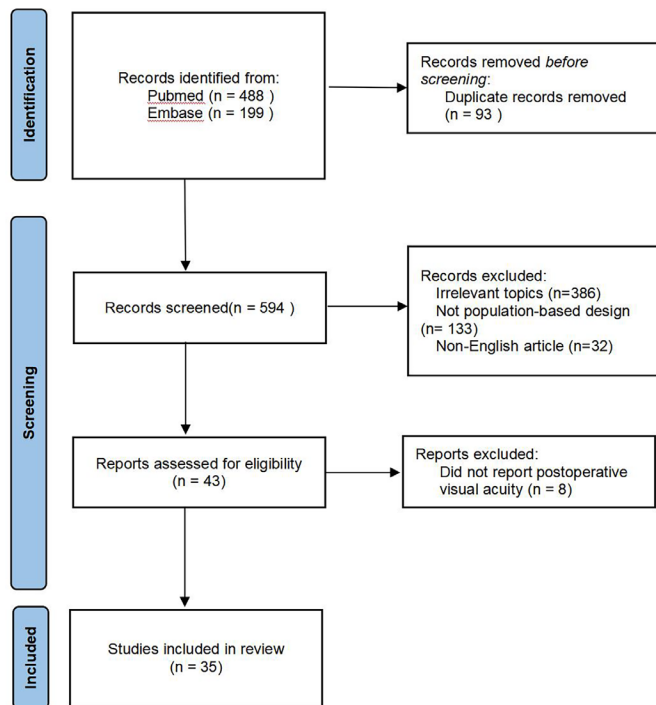


Figure 1 Flow diagram.

$\geq 20/60$  (0.32) and 81.0% with BCVA  $\geq 20/60$  (0.32), the main cause for postoperative VI was refractive error (RE) (33.0%). All the six studies in India included adult subjects ( $\geq 30$  years) with sample size ranging from 4711 to 9600. Two studies<sup>18 33</sup> reported the distribution of cataract surgery types, with manual small-incision cataract surgery as the most commonly performed (55.1% and 74.7%), followed by ECCE and phacoemulsification. The proportions of participants with postoperative PVA  $\geq 0.32$  (recorded as 6/18 or 20/60 or 20/63) ranged from 37.0% (Nangia *et al* 2011, Rural Central India)<sup>24</sup> to 74.6% (Marmamula *et al* 2016, Southern India)<sup>34</sup> and the proportions with postoperative BCVA  $\geq 0.32$  ranged from 63.0% (Nangia *et al* 2011, Rural Central India)<sup>24</sup> to 80.7% (Khanna *et al* 2012, Southeast India).<sup>27</sup> RE is the leading cause of postoperative VI (PVA  $< 0.32$ ), one exception is that ocular comorbidities was the leading cause in the study by Marmamula *et al* (2016).<sup>34</sup>

We identified two studies in Brazil. Salomão *et al* (2009)<sup>19</sup> included 3642 participants aged  $\geq 50$  years, 231 (357 eyes) patients had received cataract surgery, including 50.4% ECCE, 45.4% phacoemulsification and 3.9% ICCE. Watanabe *et al* (2019)<sup>38</sup> included 2041 participants aged  $\geq 45$  years, 176 (275 eyes) patients had received cataract surgery, including 35.3% ECCE, 62.9% phacoemulsification and 1.8% unclear. Proportions of participants with postoperative PVA of  $\geq 20/32$  (0.625),  $< 20/40$  (0.5) to 20/63 (0.32),  $< 20/63$  (0.32) to 20/200 (0.1),  $< 20/200$  (0.1) to 20/400 (0.05) and  $< 20/400$  (0.05) were 41.2%, 28.1%, 14.2%, 6.3%, 10.2% and 44.4%, 20.8%, 14.4%, 2.6%, 17.8%, respectively. The corresponding numbers for postoperative BCVA were 61.9%, 17.6%, 8.2%, 5.10%, 7.10% and 59.2%, 13.0%, 10.4%, 1.50%, 15.9%, respectively. Postoperative VI was defined as PVA  $< 0.32$  and ocular comorbidities was the leading cause of VI in both studies. Two studies were identified in Nepal. Kandel *et al* (2010)<sup>21</sup> included 5138 subjects aged  $\geq 50$  years, among whom 359 (485 eyes) participants had received ICCE or ECCE. They reported that 61.4% and 84.7% study participants achieved a postoperative PVA and

BCVA  $\geq 6/18$  (0.32), respectively. Thapa *et al*<sup>23</sup> included 4003 subjects aged  $\geq 40$  years, among whom 151 (226 eyes) participants had received cataract surgery (type not reported). The corresponding proportions of participants with postoperative PVA and BCVA  $\geq 6/18$  (0.32) were 54.4% and 72.6%, respectively. Postoperative VI was also defined as PVA  $< 6/18$  (0.32) and RE was the leading cause in Kandel *et al*<sup>21</sup>, and ocular comorbidities was the main cause in Thapa *et al*.<sup>23</sup> Of the two studies conducted in Nigeria, Imam *et al*<sup>25</sup> included 13 591 subjects aged  $\geq 40$  years and only 217 (288 eyes) participants had received cataract surgery. The proportions of participants with postoperative PVA of  $\geq 6/18$  (0.32),  $< 6/18$  (0.32) to 6/60 (0.1) and  $< 6/60$  (0.1) were 29.9%, 26% and 44.1%, the corresponding numbers for postoperative BCVA were 55.9%, 20.8% and 23.3%, respectively. In contrast to other studies, the leading cause of postoperative VI (PVA  $< 0.32$ ) was uncorrected aphakia (38.6%), followed by comorbidities (24.4%) and complications (18.8%). Odugbo *et al*<sup>26</sup> included 4115 subjects aged  $\geq 50$  years in Nigeria, they also identified a low rate of cataract surgery (119/4115) and poor surgical outcomes (postoperative PVA  $\geq 0.32$ : 25.6%). Aphakia (65.1%) and comorbidities (20.9%) were also the first two causes for postoperative VI.

Only one population-based cross-sectional study was identified for the following regions. Bourne *et al*<sup>16</sup> included 16 507 subjects aged  $\geq 30$  years in Pakistan, 1317 (1788 eyes) participants had received cataract surgery (61.0% ICCE, 34.0% ECCE). The proportion of participants with postoperative PVA and BCVA of  $\geq 6/18$  (0.32),  $< 6/18$  (0.32) to 6/60 (0.1) and  $< 6/60$  (0.1) was 29.5%, 35.3%, 34.3% and 50.1%, 27.5%, 22.1%, respectively. The top three leading causes of postoperative VI included RE (53.4%), ocular comorbidities (23.5%) and complications (21.4%). Lindfield *et al*<sup>17</sup> included 3503 subjects aged  $\geq 50$  years in Bangladesh, 170 (213 eyes) participants had received cataract surgery. The proportion of participants with postoperative PVA and BCVA of  $\geq 6/18$  (0.32),  $< 6/18$  (0.32) to 6/60 (0.1) and  $< 6/60$  (0.1) was 60.1%, 16.4%, 23.5% and 67.6%, 12.2%, 20.2%, respectively. The top three leading cause of postoperative VI in this study were comorbidities (33.8%), complications (30.6%) and RE (25.8%). Brian *et al*<sup>22</sup> included 1381 subjects aged  $\geq 40$  year in Fiji, 88 (113 eyes) participants had received cataract surgery and among the ECCE eyes, 56.6% achieved postoperative PVA  $\geq 6/18$  (0.32) and 19.7% were  $< 6/60$  (0.1). Katibeh *et al*<sup>29</sup> included 2819 subjects aged  $\geq 50$  years in Iran, 341 (526 eyes) participants had received cataract surgery. About 71.9% of the study participants achieved postoperative PVA  $\geq 6/18$  (0.32), and the major reasons for not achieving this VA criteria included comorbidities (42.6%), complications (33.8%) and RE (25.0%). Morchen *et al*<sup>31</sup> included 4471 subjects aged  $\geq 50$  years in Cambodia, cataract surgery was performed in 372 eyes. The proportion of participants with postoperative PVA of  $\geq 6/18$  (0.32),  $< 6/18$  (0.32) to 6/60 (0.1) and  $< 6/60$  (0.1) was 69.9%, 16.9%, 13.2%, respectively. Postoperative VI was defined as PVA  $< 6/60$  (0.1) in this study, and the three leading causes were comorbidities (62.5%), complications (12.5%) and RE (6.3%). Pawiroedjo *et al* (2016)<sup>32</sup> included 2998 participants aged  $\geq 50$  years in Suriname, and reported a relatively high cataract surgical coverage (1003/2998) and good surgical outcome (postoperative PVA  $\geq 0.32$ : 80.5%). Postoperative VI was also defined as PVA  $< 6/60$  (0.1) in this study, and the three leading causes were comorbidities (52.0%), RE (30.0%) and complications (11.0%). Thoufeeq *et al*<sup>36</sup> included 3020 subjects aged  $\geq 50$  years in Maldives, 850 (850 eyes) participants had received cataract surgery. The proportion of participants with postoperative PVA and BCVA of  $\geq 6/18$  (0.32),  $< 6/18$  (0.32)

to 6/60 (0.1) and <6/60 (0.1) was 67.9%, 17.3%, 14.8% and 76.6%, 10%, 13.4%, respectively. Causes for postoperative VI were not reported.

Only five population-based cross-sectional studies in HICs were identified. Barañano *et al*<sup>42</sup> included 6357 participants aged  $\geq 40$  years during 2000–2003 in California, 261 (422 eyes) participants had received cataract surgery and the proportion of participants with postoperative PVA and BCVA of  $>20/40$  (0.5),  $<20/40$  (0.5) to  $20/63$  (0.32),  $<20/80$  (0.25) to  $20/160$  (0.125) and  $<20/200$  (0.1) was 51.9%, 22.8%, 9.00%, 16.4% and 67.8%, 13.5%, 6.20%, 12.6%, respectively (table 2). Postoperative VI was defined as PVA  $<20/40$  (0.5), and the top three reasons for VI included ocular comorbidities (50.7%), RE (33.0%) and posterior capsule opacification (PCO) (7.40%). Two studies were conducted in Singapore which included participants aged 40 years and above. The study by Lavanya *et al*<sup>45</sup> was conducted during 2004 and 2006, 438 (592 eyes) patients of 3266 participants received cataract surgery, and there were 26.8% of participants with postoperative PVA  $\leq 6/18$  (0.32) and 10.8% with BCVA  $\leq 6/18$  (0.32). The study by Gupta *et al*<sup>43</sup> was conducted during 2007–2009, 486 (795 eyes) patients of 3388 participants received cataract surgery, and there were 25.5% of participants with postoperative PVA  $\leq 20/60$  (0.32) and 10.9% with BCVA  $\leq 20/60$  (0.32). The study by Keel *et al*<sup>44</sup> was from the Australian National Eye Health Survey which included 4836 participants during 2015–2016. Of the 773 (1333 eyes) patients who received cataract surgery, 77.6% achieved postoperative PVA  $\geq 6/12$  (0.5), 19.7% with PVA between 6/60 (0.1) and 6/12 (0.5) and 2.63% were  $<6/60$  (0.1). In the two Singapore studies, postoperative VI was defined as PVA  $<0.32$ , nearly 60% of VI was due to RE, followed by comorbidities and PCO. In the other two studies, PVA was defined as PVA  $<0.5$ , and the leading cause was comorbidities (50% in Australia), followed by RE and surgical complications. The most recent study by Owen *et al*<sup>46</sup> was from the IRIS study which included over 1.8 million patients who underwent bilateral cataract surgery. There were 28.8% of eyes achieved postoperative PVA  $\geq 20/20$  (1.0) with no information regarding other status of PVA nor the cause of VI.

Four cohort studies were identified with a follow-up period ranging from 5 years to 20 years (table 3). The Beijing Eye Study<sup>47</sup> is a population-based cohort study which included 4378 participants aged  $\geq 40$  years at baseline in 2001. The cataract surgical outcome was not assessed at baseline, while at the 5-year follow-up, 92 (133 eyes) participants had received cataract surgery among whom 42.1% received cataract surgery in the last 3 years. The proportion of participants with postoperative PVA and BCVA of  $>6/12$  (0.5),  $<6/12$  (0.5) to  $6/18$  (0.32),  $<6/18$  (0.32) to  $6/60$  (0.1) and  $<6/60$  (0.1) was 72.9%, 6.80%, 13.5%, 6.80% and 88%, 1.50%, 8.30%, 2.30%, respectively. Fifty percent of postoperative VI (PVA  $<6/18$ ) was attributed to RE, 38.3% to comorbidities and 7.7% to PCO. The Blue Mountain Eye Study,<sup>49</sup> which included 3654 participants aged  $\geq 49$  years during 1992–1994, reported the cataract surgical outcomes at 5-year and 10-year follow-up. The proportion of participants with postoperative PVA and BCVA  $<6/12$  (0.5) were similar at 5 (26% and 8.6%) and 10 (23% and 9.2%) years. Sixty percent of the postoperative VI was due to RE at both follow-ups. The Liwan Eye Study<sup>48</sup> included 1405 participants aged  $\geq 50$  years at baseline during 2003–2004, 62 (90 eyes) participants had received cataract surgery including 54.4% with phacoemulsification, 44.4% with ECCE and 1.2% with ICCE. Postoperative PVA (measured with pin-hole) was  $\geq 6/18$  (0.32) in 62.2% and BCVA was  $\geq 6/18$  (0.32) in 75.6% of the study population. During the 5-year follow-up, 44 of 62 participants

received phacoemulsification, the proportion of participants with pin-hole PVA and BCVA of  $\geq 6/18$  (0.32) was 59.7% and 80.6%, respectively. The leading cause of postoperative VI was ocular comorbidities at baseline and RE at 5-year follow-up in the Liwan Eye Study. Eva Monestam included 890 participants during 1997–1998 in Sweden and followed up for 20 years.<sup>50–53</sup> Phacoemulsification was the dominate type of cataract surgery (97.9% at 5-year follow-up and 100% afterwards). The proportion of participants with postoperative BCVA  $>20/40$  (0.5) at 5-year, 10-year and 15-year follow-up was 83.6%, 76% and 81%, respectively. At the 20-year follow-up, only a median postoperative BCVA of  $20/63$  was reported.

## DISCUSSION

With the continuous global effort leading to increasing cataract surgical volume in recent decades, equal attention must be paid to ensure the cataract surgical quality and adequate postoperative care.<sup>5–6</sup> Based on this systematic review, we found that there was a lack of population-based data on the post-cataract surgery VA outcomes in many countries, and existing evidence demonstrated substantial difference in the cataract surgery type, postoperative VA status as well as principle causes for postoperative VI among different countries and regions.

The majority of the identified population-based studies in this review were cross-sectional studies from LMICs, especially China and India. Cohort studies were scarce, as well as studies from HICs and many other LMICs. Understanding the long-term VA outcome after cataract surgery is of great value considering 20–40 years of life ahead after the surgery for most patients.<sup>54</sup> In addition, the VA prognosis for different types of IOLs was not addressed in existing population-based studies, perhaps due to a paucity of cases. With the increasing popularity in the use of newer IOLs, including the toric IOL and presbyopia-correcting IOL,<sup>55–56</sup> more data and prolonged observations from across the world are needed to better understand the visual outcomes of cataract surgery in the modern society for global strategic planning.

We observed significant difference in the postoperative VA between LMICs and HICs. The proportions of patients with postsurgical VA  $\geq 0.32$  were mostly below 70%, varying significantly among different LMICs (29.9% in Nigeria to 80.5% in Suriname) and even within the same LMIC country (37%–74.6% in India). In contrast, the proportions of patients with postsurgical VA  $\geq 0.32$  were all above 70% in HICs. The fact that only half of the cataract surgeries resulted in a PVA of 6/18 or better in many LMICs is of great concern. Referring to the WHO recommendation of an uncorrected VA of  $\geq 20/60$  (0.32) in at least 80% of operated eyes,<sup>57</sup> we still have a long way to go in achieving this goal in the real world, especially for LMICs.

Postoperative VI was mostly defined as a PVA  $<0.32$  ( $<0.5$  in some studies) and with varying principal causes in different studies. In the four studies from HICs, ocular comorbidities (California and Australia) and RE (both Singapore studies) were the leading causes of postoperative VI. In most LMICs, the most common causes of postoperative VI included ocular comorbidities, RE and surgical complications including the development of PCO. Sight-threatening ocular comorbidities, including glaucoma, age-related macular degeneration, diabetic retinopathy, can cause inadequate visual outcomes after the cataract surgery. A thorough preoperative examination could differentiate VI due to cataract from other causes, helping better informed surgical decision and more reasonable surgical outcome expectations.<sup>58</sup> RE is found to be another leading cause of postoperative VI,



suggesting the lack of appropriate refractive spectacles for a large proportion of patients after cataract surgery. To address this issue, greater attention should also be paid to ensure that the IOL implant is of appropriate power. The newer generations of the IOL formulas, including the Kane and Barrett Universal II formula, have been reported to be able to predict the postoperative RE with high accuracy and stability.<sup>59</sup> Adequate postoperative follow-up and timely prescription of spectacles in need are important to ensure the fulfilment of VA potential for each patient. It should also be noted that in the two studies from Nigeria, the leading cause for postoperative VI was aphakia, suggesting a high unmet need for IOL implantation in this region. Despite being easily treatable with a yttrium-aluminum-garnet-laser capsulotomy, PCO caused 3%–25% of the postoperative VI in existing studies, which suggested poor adherence to necessary postoperative follow-ups. For the vision-restoring potential of cataract surgery to be fully realised, the importance of regular postoperative follow-up care must be emphasised to all patients.

Apparently, quality control and enhancement are needed to improve the outcomes of cataract surgeries. This is important not only in better patient prognosis but also in further increasing the receipt of cataract surgeries in the population. Standard cataract surgical training for young ophthalmologists and strict quality-control system would be helpful in ensuring the quality of the surgery itself. More evidence-based studies or guidelines regarding the choice of IOL and structured postoperative follow-up management will also help in minimising the risk of correctable VI after the surgery. Previously reported barriers to cataract service were mostly related to poor accessibility, including lack of transport, low awareness, high cost and less family support.<sup>60 61</sup> Numerous global and regional action plans and campaigns have been taken to reduce these barriers, while factors that contribute to unideal VA outcomes, including inadequate preoperative examination for surgical plan, poor postoperative VA monitoring and lost to follow-up, are often neglected in the real world. Actions to integrate and coordinate the continuous medical care for postoperative patients, development of standardised follow-up process and financial support for the patients and health institutions should be implemented. The significant inequality in cataract surgical outcome between HICs and LMICs also warrants global attention and audit, as the worse VA outcomes can further lead to lower productivity and higher socioeconomic burden.<sup>2 13</sup>

## CONCLUSION

We provided a comprehensive and systematic review of visual outcomes after cataract surgery based on population-based studies worldwide during the previous 15 years. The reported visual outcomes were less ideal based on the WHO recommendation criteria, especially in LMICs. Significant inequalities in cataract surgery quality were observed within and among different countries and regions, which call for regional and global actions to tackle this problem.

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