Eye (2021) 35:3049–3055
https://doi.org/10.1038/s41433-020-01381-1

The ROYAL COLLEGE of OPHTHALMOLOGISTS

ARTICLE

Biometric refractive error after cataract and retina surgery: a systematic review and a benchmark proposal

Alba Miele[1] · Carlo Fumagalli[2] · Giacomo Abbruzzese[1] · Alfonso Savastano[1] · Stanislao Rizzo[1] · Fabrizio Giansanti[1] · Gianni Virgili[1]

Received: 22 May 2019 / Revised: 25 November 2020 / Accepted: 18 December 2020 / Published online: 8 January 2021

Abstract

Purpose To systematically review studies on refractive error after phacovitrectomy and phacoemulsification and to investigate factors associated with larger error.

Materials and methods A literature search was performed using PUBMED and EMBASE until May 2020. The articles were included in the study if they reported data about refractive error as the difference in spherical equivalent between actual vs. target refraction in patients who underwent phacovitrectomy and phacoemulsification according to the type of biometry (ultrasound or optical). An inverse variance meta-analysis technique was used to pool errors; standard deviations (SDs), which are an expression of random error, were reported descriptively as median and range of the 95% coefficient of reproducibility (95% CR: 1.96 SD).

Results Twenty-one studies (197,353 eyes) were included. The mean error obtained using optical biometry was negligible for phacoemulsification (0.04 D, 95% CI: −0.04 to 0.12; 8 studies, 587 eyes) and was consistent with larger datasets using mixed biometric methods (0.02, 95% CI −0.07 to 0.04; 5 studies, 194,522 eyes). A trend towards hyperopia was found with ultrasound biometry after phacoemulsification (+0.21 D, 0.00–0.42 D; 7 studies, 394 eyes). Mean error after phacovitrectomy was clinically insignificant with optical biometry (−0.10 D, −0.22 to 0.02;, 8 studies, 453 eyes), and) and a mild myopic shift was possible with ultrasound biometry (−0.39 D, 95% CI: −0.68 to −0.09 D; 6 studies, 529 eyes). The 95% CR was greater and more variable with ultrasound biometry in patients who underwent phacovitrectomy (median 1.75 D, range 0.47–2.5) while it was consistent and lower with optical biometry in patients who underwent phacoemulsification (median 0.96 D, range 0.60–1.2]).

Conclusions Phacovitrectomy causes a mild myopic shift compared to phacoemulsification, which is clinically relevant only with ultrasound biometry. Furthermore, our review provides estimates of fixed and random error for postoperative vs. target spherical equivalent as a continuous variable, that is easy to use as benchmark for quality assurance.

Introduction

Cataract surgery is the most common minimally-invasive procedure performed worldwide and serves multiple purposes, from improvement of pre-existing refractive error to optimisation of uncorrected visual acuity. Phacoemulsification combined with vitrectomy is also recommended when cataract prevents optimal visualisation of the retina in macular disease [1–4].

Accurate pre-operative measurements and optimisation of IOL power formulas are key to reduce post-operative refractive error and guarantee the best refractive outcome possible [5, 6].

A mismatch between expected and achieved refractory outcome is inevitable. A potential source of mismatch is the accuracy of the device used for measuring axial length (AL), such as optical biometry rather than ultrasound (US) biometry. Formulas for intraocular lens power calculation (Haigis, Hoffer –Q, Holliday, SRK/T) and IOL constants can be optimised to reduce refractive error but none are

✉ Alba Miele
albamiele@hotmail.it

[1] Ophthalmology Clinic, Department of Neurosciences, Psychology, Drug Research and Child Health (NEUROFARBA), University of Firenze and AOU Careggi, Firenze, Italy

[2] Department of Experimental and Clinical Medicine, University of Florence, Florence, Italy

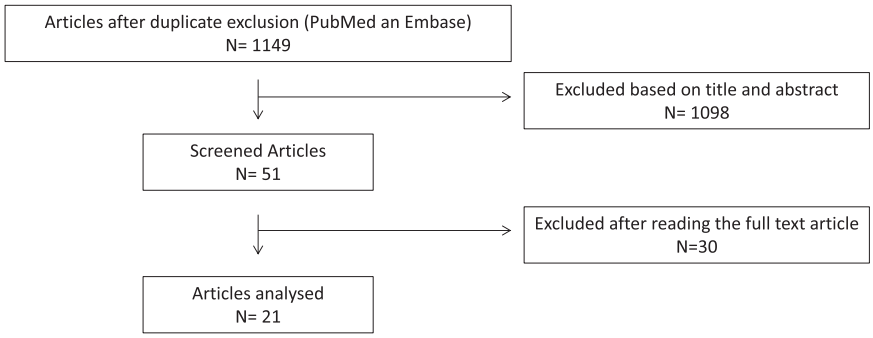

Fig. 1 PRISMA flow diagram updated in May 2020. The PRISMA flow diagram for article selection based on searches conducted in May 2020.

ideal when vitrectomy is added to cataract surgery [7]. The effect of intraocular silicone oil or gas tamponade can displace the lens/IOL and reduce anterior chamber depth (ACD) [8].

Phacovitrectomy, which involves combining phacoemulsification and vitrectomy in a single procedure is increasingly used, especially for the treatment of macular holes and epiretinal membranes [9, 10]. Despite all the advantages of phacovitrectomy, individual studies have shown inconsistent findings regarding the accuracy of the prediction of intraocular lens power calculations compared to phacoemulsification [3, 10–12]. The latter is calculated as the intended spherical equivalent to predicted spherical equivalent (actual error minus the predicted). The negative refractive error is called myopic shift, while the positive refractive error is called hypermetropic shift [13, 14].

The aim of this study was to systematically review studies on refractive error after phacovitrectomy and phacoemulsification and to investigate factors associated with larger error.

Materials and methods

A search was performed until May 2020 on Pubmed and Embase using the following search strings:

1) ((((Optical OR ultrasound) and biometr)) AND ((macular AND (hole* OR pucker*)) OR Epiretinal membrane* OR Retinal detach*)) AND (phacovitrectom* OR Cataract* OR phaco-vitrect* OR Phacoemulsificat* OR phaco-emulsificat*)) AND (((postoperat* OR post-operat* OR change* OR outcome* OR target?) OR refract*) OR "myopic shift" OR "intraocular lens"*

2) (((((Optical OR ultrasound) AND biometr))AND ((Macular AND (hole* OR pucker*))OR epiretinal membrane*or retinal detach*)) AND (phacovitrectom* OR cataract* Or phaco-vitrect* OR phacoemulsificat*OR phacoemlusificat*)).*

To identify the studies to be included in the systematic review, initially titles were evaluated, then the abstract and finally the complete text of the article. The articles included in the study had to enrol patients in whom the intraocular lens was positioned in the capsular bag and the patient sample had to be greater than five. Those studies that did not report continuous refractive error after phacovitrectomy or phacoemulsification were excluded. Studies were also excluded from the systematic review if the lens was routinely positioned in the ciliary sulcus. Finally, when a two-stage intervention was used in separate surgical interventions (PPV and subsequently phacoemulsification), we considered it as a single phacoemulsification.

Once the articles were selected, data were extracted regarding the type of intervention performed (phacoemulsification or phacovitrectomy), the refractive error after these operations, the biometric technique used (optical or ultrasound), the patient's condition and the formula used. We also recorded when patients were treated with silicone oil as an intraocular tamponade. When studies reported data obtained on the same sample with different formulas (SRK/T, Holladay1/2, Hoffer Q, Barrett universal 2) we extracted the results of the SRK/T formula as it was the most used formula.

The search for articles and data processing were performed by two operators. A third impartial reviewer was involved in cases of disagreement.

Statistical analyses

An inverse variance meta-analysis technique was used to pool refractive errors; standard deviations (SDs), which are an expression of random error, were reported as median and range of the 95% coefficient of reproducibility (CR: 1.96*SD). All analyses were carried out using Stata 15.2 software (StataCorp, College Station, TX, USA).

Results

Results of searches

Figure 1 summarises the PRISMA flow Diagram for article selection based on searches conducted in May 2020.

Our systematic review was based on a total of 21 articles (197,353 eyes), including: 13,119 eyes from 19 studies conducted at a single centre; 8677 eyes from a large study using an electronic database in Scotland (number of centres not specified, seven consultants operated nearly all patients); 175,557 cases from a Europe-wide database in 12 countries (53 sites, with the Netherlands as a single site) from a recent study based on the EUREQUO registry [15].

Of the 21 articles included in this review, 8 compared refractive error between phacovitrectomy for maculopathies and phacoemulsification alone for cataract, [3, 9–12, 16–18] 9 studies investigated phacoemulsification alone [3, 10, 11, 17, 19–21], and 6 phacovitrectomy alone. [5, 12, 13, 22, 23] In 14 studies on phacovitrectomy, 9 included only macular diseases [3, 5, 10, 12, 18, 21, 24–26] and 5 included a miscellanea of retina disease including retinal detachment [11, 13, 22, 27, 28].

Regarding biometry techniques, 4 studies compared optical with US biometry [11, 16, 26, 29], 6 studies each used optical [5, 8, 12, 13, 23, 27] or US [3, 17–19, 21, 28] biometry only. Among studies using US biometry, 2 articles reported the refractive error after phacoemulsification in eyes with silicone oil [8, 27].

Abu El Einen et al. [27], reported data in patients operated on cataracts after vitrectomy with silicone oil and we only extracted the data relating to the B-scan ultrasound, considering the A-scan ultrasound more subject to error.

Quantitative results

Figure 2 shows the meta-analysis of the mean differences between predicted and target spherical equivalent. In this figure, study weights (the boxes corresponding to point estimates of each study) were derived by the fixed-effects method for presentation purposes, whereas both fixed and random effects meta-analyses are presented. As expected, given its large sample size, EUREQUO had 90% of the fixed-effect weight in the meta-analysis, but only 6% in the random-effect model, meaning that smaller studies are as informative as large studies in random-effects models. Nonetheless, fixed and random effects point estimates are very similar, suggesting the robustness of our meta-analysis.

The mean spherical equivalent error (dioptre) obtained with optical biometry was close to nil for phacoemulsification, with 95% CI excluding clinically significant mean error (0.04, 95% CI −0.04 to 0.12; 8 studies, 587 eyes). The 95% predictive interval, which includes between-study variance and is interpreted as the interval of possible results in a new study, was −0.22 to 0.30 D, also suggesting little imprecision. These results matched those of larger studies (5 studies, 194,522 eyes), including two electronic datasets, using mixed biometric methods (0.02, 95% CI −0.07 to 0.04) which should have used optical biometry in nearly all cases, according to standard clinical practice. A slightly hyperopic shift was recorded when ultrasound biometry was used after phacoemulsification (0.21, 95% CI 0.0–0.42; 7 studies, 394 eyes) with relatively large predictive intervals (−0.48 to 0.91) because of larger heterogeneity of study estimates.

Mean spherical equivalent error after phacovitrectomy was also small when optical biometry was used (−0.10, 95% CI −0.22 to 0.02; 8 studies, 453 eyes) with larger 95% predictive interval with respect to phacoemulsification (−0.48 to 0.28). As expected, the mean error was larger with ultrasound biometry, causing a myopic shift (−0.39, 95% CI: −0.68 to −0.09; 6 studies, 529 eyes) and large between study (95% predictive interval −1.45 to 0.68).

Figure 3 shows the results of the individual studies including the mean error (or fixed bias) with 95% Bland–Altman limits of agreement (±1.96 times the SD of the differences). The 95% CR is also presented, which indicates the absolute value of the random component of the error once the fixed bias is accounted for.

As expected, the 95% CR (in dioptres) was smaller for studies where optical biometry was used with phacoemulsification, the errors being between ±0.63 and ±1.2 with a median of ±0.96. This error was slightly smaller than that found in large studies using mixed or unspecified, biometry techniques, which should have used optical biometry in all but few difficult cases.

When optical biometry was used with phacovitrectomy, a greater error was obtained, ranging between ±0.96 and ±1.7, with a median of ±1.4.

Ecobiometry resulted in a greater and more variable error after phacoemulsification, between ±1.1 and ±2.6, with a median of ±1.7. Noticeably, two of these studies performed phacoemulsification after vitrectomy for retinal detachment, with silicone oil making ecobiometry difficult to perform and less precise. The same result was found for ecobiometry after phacovitrectomy, with errors between ±0.47 and ±2.5 and a median of ±1.65.

Discussion

Our study has systematically reviewed the evidence on the biometric error using the difference between intended and target spherical equivalent with optical or ultrasound biometry after phacoemulsification or phacovitrectomy. We found that optical biometry yields no mean error after phacoemulsification, whereas ecobiometry induces an average mild hyperopic shift of about +0.2 D. Greater mean differences are recorded after phacovitrectomy, with a myopic shift between −0.2 and −0.4 D for optical and ecobiometry, respectively.

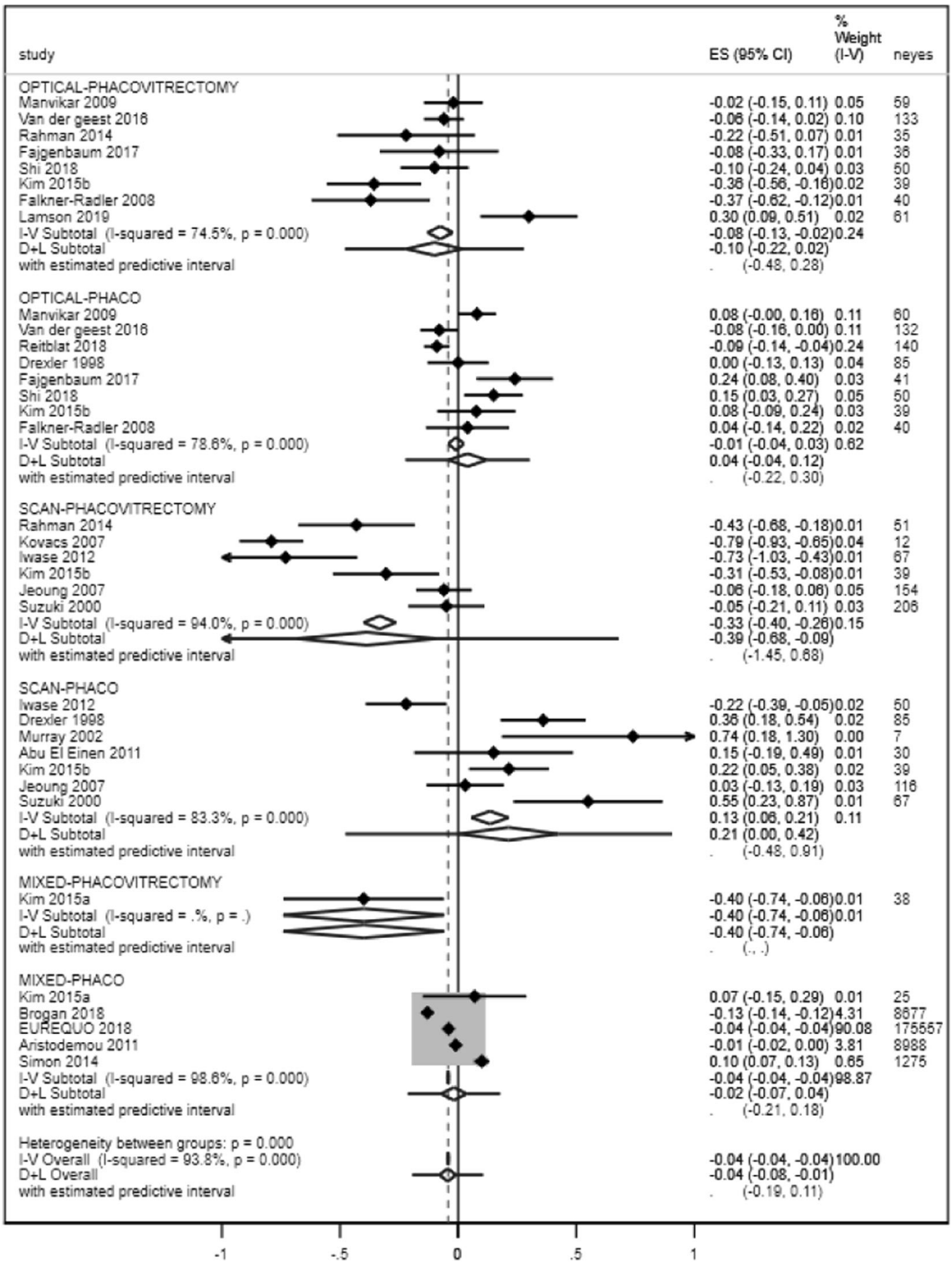

Fig. 2 Meta-analysis of the mean differences between predicted and target refraction. In this figure, study weights (the boxes corresponding to point estimates of each study) were derived by the fixed-effects method for presentation purposes, whereas both fixed and random effects meta-analyses are presented.

Moreover, we provide a description of the variability of the random error across studies, expressed as 95% CR, which shows the expected biometric error width around the fixed bias. We found that the 95% CR is expected to be within ±1 dioptre for 95% of patients for optical biometry after phacoemulsification; using our estimates, the 99% CR can be computed with an increase by about 30%, i.e. to ±1.3 dioptres, meaning that larger errors are expected in one in 100 patients. These values could be used as a basis for quality assurance and patient information.

Biometric error is substantially larger after phacoemulsification when ecobiometry is used (95% CR ± 1.7 dioptre, 99% CR about ±2.2 dioptre); moreover, the average spherical equivalent error was variable across studies,

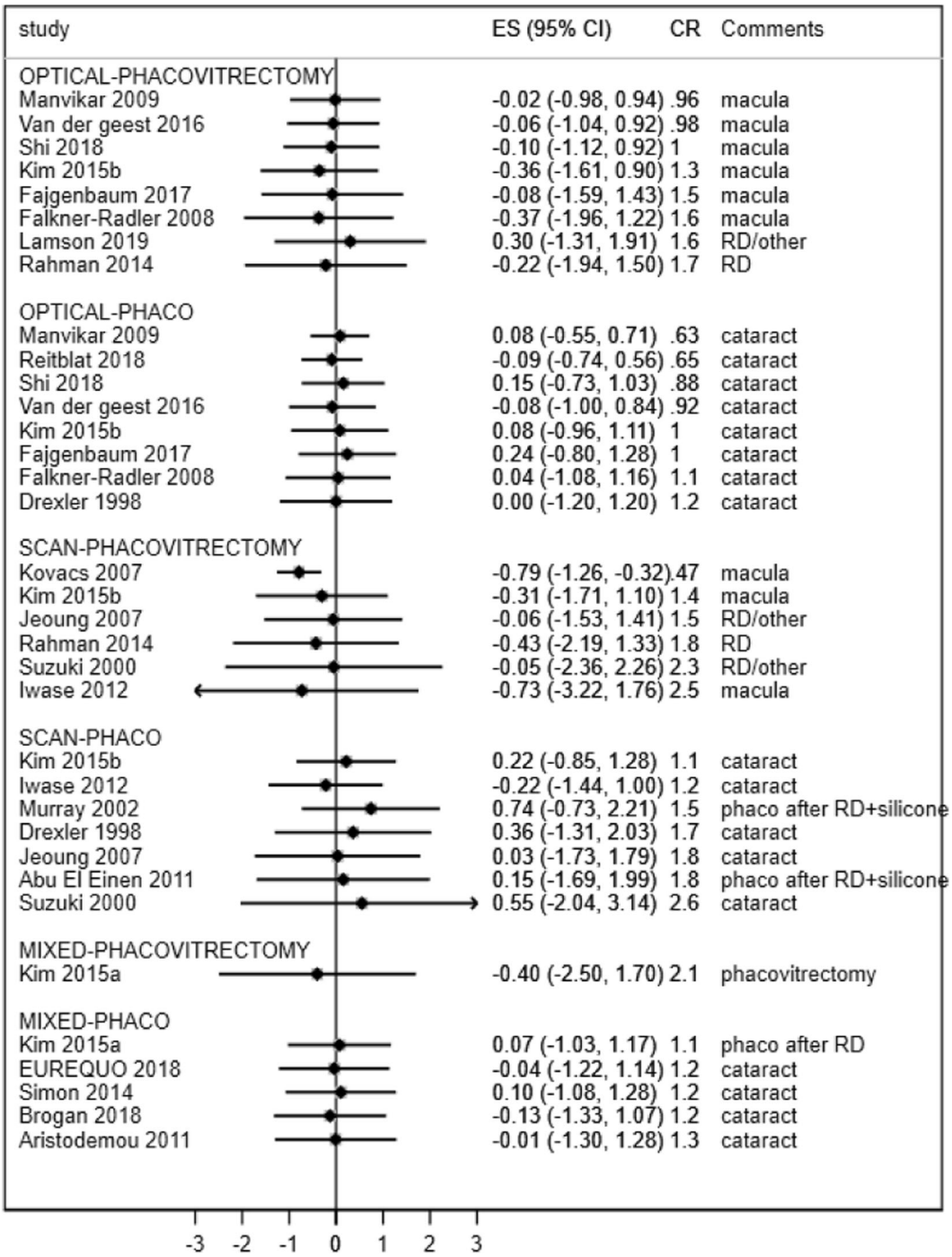

Fig. 3 The results of the individual studies including the mean error (or fixed bias) with 95% Bland–Altman limits of agreement, which express the maximum error obtained in the study, are presented. The 95% CR is also presented which indicates the random component of the error once the fixed bias is adjusted for.

ranging from about 1–2.5 dioptres, meaning that patient selection, the quality of ecobiometry or other clinical factors could play a role to explain the differences between studies.

The random error was slightly larger with optical biometry after phacovitrectomy, with a median 95% CR value of ±1.3 dioptres and upper values of ±1.7 dioptres, meaning that the 99% CR would be a median ±1.7 and upper values of ±2.2 dioptres respectively. Errors are even larger when ecobiometry is used with phacovitrectomy. Considering fixed and random error, as well as heterogeneity of results, we suggest that biometric error up to 3 dioptres is rare, but not exceptional, after phacovitrectomy.

When searching for the evidence for our review, we did not find previous meta-analyses of spherical equivalent

error as a continuous measure after cataract surgery or phacovitrectomy. In 2017, the UK National Institute for Clinical Excellence (NICE) conducted an evidence review in support of cataract surgery guidelines and found 17 studies providing data on various questions regarding biometry, focusing on several comparisons between biometric formulas and IOL type, including accuracy in eyes with different axial length, surgery in eyes with previous refractive surgery, and refinement based on second-eye surgery. This large assessment used Bayesian network meta-analyses to pool mean absolute error and the proportion within 0.25, 0.5 and 1 dioptre of target refraction, and focused on comparisons between techniques and devices rather than on the variability of biometric error across providers, which is the scope of our review.

Our meta-analysis of biometric error as a continuous measure has advantages in terms of transferability of the results. In fact, the SD of the biometric error can be precisely measured in a small sample of about 100 individuals [30], which would be insufficient to reliably estimate the proportion of subjects exceeding 1 dioptre, which is currently 5 patients in 100 interventions. We suggest that a collection of data from a representative random sample of consecutive cases may be used as the minimum sample size for quality assurance audits using continuous spherical equivalent error.

Our study has several limitations. First of all, we did not search for unpublished information from reports that may have been collected as part of quality assurance initiatives in individual services or health networks. Such information is not only be difficult to retrieve, but also impossible to collect systematically. Moreover, systematic reviews generally adopt validated instruments to assess risk of bias of included studies. This was not possible in our review since we are not aware of any tool that may be used in reviews of measurement error. We suggest that studies should include consecutive patients and motivate any missing follow-up data and exclusions, for example because of complications during cataract surgery. Studies could also report on any quality assurance interventions adopted, which may enable researchers to investigate sources of heterogeneity and identify good practice.

A further limitation of our review concerns our analysis plan, which did not aim to extract the proportion of patients within ±1 dioptre of target refraction, which has been widely used in studies on biometric accuracy after cataract surgery. Nonetheless, we have presented above the advantages of our method.

Finally, we did not provide subgroup data on factors that influence biometric error. We refer to EUREQUO [15], other reviews [26, 28, 29, 31], as well as to the NICE guidelines [32] for systematic reviews on biometric error in hyperopic or myopic eyes, or after refractive surgery.

Implication for clinical practice and future research

Our study showed that phacovitrectomy leads to mild myopic shift compared to phacoemulsification alone. This myopic shift is more evident using ultrasound biometry, whereas it is clinically insignificant if optical biometry is used. Furthermore, acceptable limits for biometric error, which can be reasonably assumed to be our 99% CR estimates, were estimated to be 1.3 D for phacoemulsification and 1.7 D for phacovitrectomy. This data can be used as a benchmark and information to the patient.

Summary

What was known before

- Phacovitrectomy causes a mild myopic shift compared to phacoemulsification.
- The myopic shift is clinically relevant only with ultrasound biometry.
- The myopic shit is clinically insignificant if optical biometry is used.

What this study adds

- Furthermore, acceptable limits for biometric error, which can be reasonably assumed to be our 99% CR estimates, were estimated to be 1.3 D for phacoemulsification and 1.7 D for phacovitrectomy.
- This data can be used as a benchmark and information to the patient.

Author contributions MA and VG designed the study, carried out data extraction, drafted and clinically reviewed the manuscript the manuscript. VG performed the statistical analysis. FC carried out data extraction and drafted manuscript. AG, SA, RS, FG drafted and critically reviewed the manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

1. Gillies M, Brian G, La Nauze J, Le Mesurier R, Moran D, Taylor H, et al. Modern surgery for global cataract blindness: preliminary considerations. Arch Ophthalmol. 1998;116:90–92.

2. Vasavada AR, Raj SM. Cataract treatment where resources are scarce. Lancet. 2005;365:550–1.
3. Manvikar SR, Allen D, Steel DHW. Optical biometry in combined phacovitrectomy. J Cataract Refract Surg. 2009;35:64–9.
4. Seider MI, Michael Lahey J, Fellenbaum PS. Cost of phacovitrectomy versus vitrectomy and sequential phacoemulsification. Retina. 2014;34:1112–5.
5. Kovacs I, Ferencz M, Nemes J, Somfai G, Salacz G, Recsan Z. Intraocular lens power calculation for combined cataract surgery, vitrectomy and peeling of epiretinal membranes for macular oedema. Acta Ophthalmol Scand. 2007;85:88–91.
6. Lee AC, Qazi MA, Pepose JS. Biometry and intraocular lens power calculation. Curr Opin Ophthalmol. 2008;19:13–7.
7. Zhang Z, Miao Y, Fang X, Luo Q, Wang Y. Accuracy of the Haigis and SRK/T formulas in eyes longer than 29.0 mm and the influence of central corneal keratometry reading. Curr Eye Res. 2018;43:1316–21. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85050525705&doi=10.1080%2F02713683.2018.1488265&partnerID=40&md5=1727a52ff90553e55cf54d1a1cfc2e0b.
8. Murray DC, Durrani OM, Good P, Benson MT, Kirkby GR. Biometry of the silicone oil-filled eye: II. Eye. 2002;16:727–30.
9. Fajgenbaum MAP, Robins J, Williamson TH. Refractive outcomes using the lenstar optical low coherence reflectometry biometer in phacovitrectomy for epiretrinal membranes and macular holes. Open J Ophthalmol. 2017;7:216–24.
10. van der Geest LJ, Siemerink MJ, Mura M, Mourits MP, Lapid-Gortzak R. Refractive outcomes after phacovitrectomy surgery. J Cataract Refract Surg. 2016;42:840–5.
11. Kim M, Kim HE, Lee DH, Koh HJ, Lee SC, Kim SS. Intraocular lens power estimation in combined phacoemulsification and pars Plana vitrectomy in eyes with epiretinal membranes: a case-control study. Yonsei Med J. 2015;56:805–11.
12. Iwase T, Oveson BC, Nishi Y. Inherent possibility of refraction error for phacovitrectomy. Clin Exp Ophthalmol. 2013;41:302–3.
13. Suzuki Y, Sakuraba T, Mizutani H, Matsuhashi H, Nakazawa M. Postoperative refractive error after simultaneous vitrectomy and cataract surgery. Ophthalmic Surg Lasers. 2000;31:271–5.
14. Hamoudi H, La, Cour M. Refractive changes after vitrectomy and phacovitrectomy for macular hole and epiretinal membrane. J Cataract Refract Surg. 2013;39:942–7.
15. Lundström M, Dickman M, Henry Y, Manning S, Rosen P, Tassignon MJ, et al. Risk factors for refractive error after cataract surgery: Analysis of 282811 cataract extractions reported to the European Registry of Quality Outcomes for cataract and refractive surgery. J Cataract Refract Surg. 2018;44:447–52.
16. Brogan K, Diaper CJM, Rotchford AP. Cataract surgery refractive outcomes: representative standards in a National Health Service setting. Br J Ophthalmol. 2019;103:539–43.
17. Shi L, Chang JS, Suh LH, Chang S. Differences in refractive outcomes between phacoemulsification for cataract alone and combined phacoemulsification and vitrectomy for epiretinal membrane. Retina. 2018.
18. Falkner-Radler CI, Benesch T, Binder S. Accuracy of preoperative biometry in vitrectomy combined with cataract surgery for patients with epiretinal membranes and macular holes. Results of a prospective controlled clinical trial. J. Cataract Refract. Surg. 2008;34:1754–60.
19. Reitblat O, Levy A, Kleinmann G, Assia EI. Accuracy of intraocular lens power calculation using three optical biometry measurement devices: the OA-2000, Lenstar-LS900 and IOLMaster-500. Eye. 2018;32:1244–52.
20. Drexler W, Findl O, Menapace R, Rainer G, Vass C, Hitzenberger CK, et al. Partial coherence interferometry: a novel approach to biometry in cataract surgery. Am J Ophthalmol. 1998;126:524–34.
21. Fajgenbaum MAP, Robins J, Williamson TH. Refractive outcomes using the lenstar optical low coherence reflectometry biometer in phacovitrectomy for epiretrinal membranes and macular holes. Open J. Ophthalmol. 2017;7:216–24.
22. Rahman R, Bong CX, Stephenson J. Accuracy of intraocular lens power estimation in eyes having phacovitrectomy for rhegmatogenous retinal detachment. Retina. 2014;34:1415–20.
23. Jeoung JW, Chung H, Yu HG. Factors influencing refractive outcomes after combined phacoemulsification and pars plana vitrectomy: results of a prospective study. J Cataract Refract Surg. 2007;33:108–14.
24. Hotte GJ, de Bruyn DP, de Hoog J. Post-operative refractive prediction error after phacovitrectomy: a retrospective study. Ophthalmol Ther. 2018;7:83–94.
25. Kim M, Park YS, Lee DH, Koh HJ, Lee SC, Kim SS. Comparison of surgical outcome of 23-gauge and 25-gauge microincision vitrectomy surgery for management of idiopathic epiretinal membrane in pseudophakic eyes. Retina. 2015;35:2115–20.
26. Simon SS, Chee YE, Haddadin RI, Veldman PB, Borboli-Gerogiannis S, Brauner SC, et al. Achieving target refraction after cataract surgery. Ophthalmology. 2014;121:440–4.
27. Abu El Einen KG, Shalaby MH, El Shiwy HT. Immersion B-guided versus contact A-mode biometry for accurate measurement of axial length and intraocular lens power calculation in silicone-nized eyes. Retina. 2011;31:262–5.
28. Lamson TL, Song J, Abazari A, Weissbart SB. Refractive outcomes of phacoemulsification after pars plana vitrectomy using traditional and new intraocular lens calculation formulas. J Cataract Refract Surg. 2019;45:293–7.
29. Aristodemou P, Sparrow JM, Kaye S. Evaluating refractive outcomes after cataract surgery. Ophthalmology. 2019;126:13–18. https://doi.org/10.1016/j.ophtha.2018.07.009.
30. Lu MJ, Zhong WH, Liu YX, Miao HZ, Li YC, Ji MH. Sample size for assessing agreement between two methods of measurement by Bland-Altman Method. Int. J. Biostat. 2016;12:/j/ijb.2016.12.issue-2/ijb-2015-0039/ijb-2015-0039.xml.
31. Melles RB, Holladay JT, Chang WJ. Accuracy of intraocular lens calculation formulas. Ophthalmology. 2018;125:169–78. https://doi.org/10.1016/j.ophtha.2017.08.027.
32. Cataracts in adults: management. 2018. NICE Guideline [NG77] (26 October 2017), www.nice.org.uk/guidance/ng77.