Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

The Royal College of Ophthalmologists' National Ophthalmology Database study of cataract surgery: Report 17, A risk factor model for posterior capsule rupture

Peng Yong Sim

pengyong.sim@nhs.net

Moorfields Eye Hospital https://orcid.org/0000-0001-5500-2634

Paul Donachie

Alexander Day

John Buchan

London School of Hygiene and Tropical Medicine https://orcid.org/0000-0003-1005-7011

Article

Keywords:

Posted Date: February 12th, 2024

DOI: https://doi.org/10.21203/rs.3.rs-3796147/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Additional Declarations: There is no conflict of interest

Version of Record: A version of this preprint was published at Eye on September 19th, 2024. See the published version at https://doi.org/10.1038/s41433-024-03344-2.

Abstract

Background/Objectives

To create a risk factor model for posterior capsule rupture (PCR) during cataract surgery.

Subjects/Methods

Eligible cataract operations were performed between 01/04/2016 and 31/03/2022 in centres supplying data to the national cataract audit on at least 50 eligible operations with complete data for patients' gender and age at surgery, anterior chamber depth (ACD) measurement and preoperative visual acuity (VA). A logistic regression model was fitted to identify risk factors for PCR.

Results

This analysis included 961 208 cataract operations performed on 682 381 patients from 136 participating centres by 3 198 surgeons. The final PCR risk factor model included surgical and patient factors comprising surgeon grade, patients' gender and age, ability to lie flat and/or cooperate, diabetic status and an interaction between age and gender. Ocular factors were first or second eye surgery, ACD, preoperative VA, previous intravitreal therapy, pupil size, the presence or absence of amblyopia, brunescent / white / mature cataract, diabetic retinopathy, glaucoma, high myopia, previous vitrectomy and pseudoexfoliation / phacodonesis.

The highest influencing risk factors were surgery by less experienced trainee surgeon, younger male patients and the presence of pseudoexfoliation / phacodonesis.

Conclusion

Various surgical, patient and ocular factors increase the risk of PCR during cataract surgery. Appropriate case allocation should balance the risk to the patient with the requirement for trainee surgeons to gain experience. This risk factor model permits estimation of individualised risks for patients and allows risk-adjustment for surgeons to evaluate their PCR rates based on case complexity.

Introduction

Cataract surgery continues to be the most commonly performed elective surgical procedure in the UK, with around 500 000 operations performed in the 2021–2022 NHS year. Since its inception in 2010, the Royal College of Ophthalmologists National Ophthalmology Database (RCOphth NOD) audit has established itself to be an important quality assurance measure and research tool, with several analyses published over the last decade[1–13]. Given its ever expanding dataset, there is a need for continual analyses to ensure up-to-date, high-quality evidence to drive quality improvement and national benchmarking of surgical outcomes.

Posterior capsular rupture (PCR) remains one of the most common complications of cataract surgery and is a risk factor for poor visual prognosis[14]. Following PCR, there is a higher relative risk (RR) of severe sight loss (RR, 15.5) [publication pending] and secondary complications such as cystoid macular oedema (RR, 2.6)[15], endophthalmitis (RR, 7.2)[10] and retinal detachment (RR, 20.4)[3]. PCR also imposes a substantial additional financial cost burden to health care systems due to the need for additional visits and interventions[16,17].

This RCOphth NOD analysis aims to provide an update to the now 15-year-old risk stratification system for PCR from the previous Cataract National Dataset[18] and also the RCOphth NOD PCR risk adjustment model fitted in 2015[19]. Over this time period, PCR rates have more than halved from 1.95%[1] to 0.87% in the latest RCOphth NOD audit annual report for 2021-2022[20]. The observed decline has a variety of potential causes, such as the introduction of simulator training amongst trainee surgeons[6], improvement in instrumentation (e.g. use of silicone-tipped handpieces[21]) and an increasing trend toward surgery on younger

and healthier eyes[22]. The determinants of PCR rate are also likely to have changed over time, with more recently reported novel risk factors for PCR such as previous intravitreal injections[23] and corneal opacities[24]. On a global scale, an up-to-date risk stratification system is required to permit meaningful comparison of the RCOphth NOD dataset with those of other countries[24,25], to facilitate the development of a bespoke international benchmarking system and to be able to advise patients before surgery of their specific material risk.

Methods

The RCOphth NOD is open to centres performing both NHS funded and private cataract surgery in England, Northern Ireland, Scotland, Wales, and the Channel Islands which include NHS centres, independent sector treatment centres (ISTCs) and private providers. The data, compliant with the RCOphth minimum national cataract dataset, is recorded on electronic medical records (EMRs) or in-house databases and submitted annually for cataract operations using phacoemulsification to treat patients aged 18 years or older, where the primary intention was cataract surgery and not combined 'cataract + other' surgery, unless the 'other' surgery formed part of the cataract operation (e.g., an operative manoeuvre to increase pupil size). Cases where PCR is expected as part of surgery, such as posterior polar or traumatic cataracts, are excluded from NOD analyses. Further information on audit eligible cataract operations can be found on the audit website (www.nodaudit.org.uk).

The study period comprised cataract operations performed between 01/04/2016 and 31/03/2022 which constitutes 6 completed NHS years. Eligible for this analysis are National Cataract Audit eligible cataract operations with data for patients' gender and age at surgery, anterior chamber depth (ACD) and preoperative visual acuity (VA). To remove data for potentially abnormal eyes or erroneous data entry, operations are excluded if the recorded ACD was <1.5mm or >4.5mm, or if the recorded axial length (AL) was <18mm. Only data from contributing centres with at least 50 cataract operations satisfying the above are included.

For this analysis, data was recorded on either the Medisoft EMR system (Medisoft Ophthalmology, Medisoft Limited, Leeds, UK, www.medisoft.co.uk), OpenEyes EMR system (www.openeyes.org.uk), or in-house databases compliant with the RCOphth national cataract dataset (https://www.rcophth.ac.uk/standards-and-guidance/audit-and-data/clinical-data-sets).

The grade of operating surgeon was categorised as consultant surgeons, career grade non-consultant surgeons (associate specialists, staff grades and trust doctors), more experienced trainee surgeons (fellows and specialty trainees / registrars years 3-7), and less experienced trainee surgeons (senior house officer, specialty trainees / registrars years 1-2 and foundation doctors).

Preoperative VA was defined as the best recorded distance VA (corrected or uncorrected but not pinhole) that is closest to the date of surgery, including the day of surgery and within 6 months prior to surgery. For numeric calculations, the extreme low vision estimates from the LogMAR chart representing count fingers (CF), hand movements (HM), perception of light (PL) and no perception of light (NPL) are replaced with 2.10, 2.40, 2.70 and 3.00, respectively[26].

To identify potential risk factors for PCR, a logistic regression model was fitted with cluster adjustment for robust standard errors, where surgeons, their grade and centre they operated in were used to create the clusters. Thus, surgeons with data in different centres have data considered as separate clusters for each centre, and similarly their operative record at different surgeon grades are considered as separate clusters.

The covariates considered as potential risk factors are known before cataract surgery starts. They concern surgeon, patient and ocular factors that could potentially influence the chance of PCR. All candidate covariates were first investigated using Chi-squared tests for categorical covariates, and Student's t-tests with the Welch adjustment for unequal variance for continuous covariates. For the categorical covariates, only those indicating association at the 1% level ($p<0.01$) from the univariate analysis were considered in the risk factor modelling. This restriction did not apply to the continuous covariates, which were all carried through to the risk factor modelling due to clinical relevance and being continuous over a discreet range which could lead to significant differences over their ranges at the multivariate but not univariate level.

The categorical variables indicating univariate association at the 1% level, plus the continuous covariates and an interaction term for patients' gender and age, were fitted to a multivariate logistic regression model with cluster adjustment for surgeons, their grade and centre the operation was performed in. The final PCR risk factor model was created using backwards selection from the 'full' model to the 'best fitting' model. Covariates were first removed if there was no significance at the 1% level ($p>0.01$), and then any remaining covariates indicating significance between 0.1% and 1% ($p>0.001$ & $p<0.01$) were all individually removed and models compared using the likelihood ratio test and assessment of the Akaike Information Criterion, and retained in the model if removal indicated no improvement to model fit.

The use of stages decreasing significance thresholds was adopted due to the increased chance of detecting very small significant differences from the large sample size, and to minimise negative impacts of possible overfitting. It is feasible this approach does not produce the best model for the sample, but is practical for a very large sample where some covariates are for rare diseases, and to attempt to remove covariates with minimal clinical differences that otherwise could be found statistically significant if using a higher significance level. The full equation of the final model used to estimate the probability of PCR for each operation is detailed in Supplementary File.

The lead clinician and Caldicott Guardian (responsible nominee for data protection) at each centre provided written approval for anonymised data extraction. Ethical permission was not required for this analysis due to being viewed as audit or service evaluation. This study was conducted in accordance with the Declaration of Helsinki and the UK Data Protection Act. All analyses were performed using STATA 18 (StataCorp. 2023. Stata Statistical Software: Release 18. College Station, TX: StataCorp LLC).

Results

Within the study period, 1 453 374 eligible cataract operations were submitted with data for patients' gender and age. Excluded from this are 492 124 (33.9%) operations for the following reasons; 297 315 had no recorded ACD measurement, 193 080 had no preoperative VA, 1 701 had a recorded ACD of < 1.5mm or > 4.5mm, and 28 had a recorded AL of < 18mm. A further 42 operations from five centres were removed as these centres had < 50 operations left in the sample after applying the exclusion criteria above.

Eligible for the risk factor modelling were 961 208 cataract operations performed in 136 participating centres: 73 English NHS trusts (578 683; 60.2%), 58 ISTCs providing NHS funded and private fee-paying surgery (365 295; 38.0%), three Welsh health boards (12 528; 1.3%), one centre from Guernsey (2 415; 0.3%) and one fully private fee-paying provider (2 287; 0.2%). The range in the number of operations performed by the centres was 144 to 28 414.

The 961 208 operations were performed on 473 074 (49.2%) left eyes and 488 134 (50.8%) right eyes from 682 381 patients by 3 198 surgeons, 686 (21.5%) of whom had data for more than one grade of surgeon; 1 521 consultant surgeons performed 738 527 (76.8%) operations, 349 career grade non-consultant surgeons performed 57 629 (6.0%) operations, 1 571 more experienced trainee surgeons performed 141 452 (14.7%) operations and 443 less experienced trainee surgeons performed 23 600 (2.5%) operations. The median number of operations performed by surgeons was 93 (range; 1 to 21 473).

First eye surgery was performed in 569 154 patients where 326 572 (57.4%) were female and the median age at surgery was 75.7 years (interquartile range; 69.0–81.7 years). Second eye surgery was performed in 391 154 patients where 229 796 (58.7%) were female and the median age at surgery was 76.7 years (interquartile range; 70.2–82.3 years). Immediate sequential bilateral cataract surgery (ISBCS) was performed in 450 patients where 261 (58.0%) patients were female and the median age at surgery was 75.0 years (interquartile range; 65.2–81.8 years). Over the study period, 278 377 (40.8%) non-ISBCS patients had surgery to both eyes, where the median time between the two operations was 3.0 months (range one day to 6.0 years).

PCR risk factor model

At the univariate level all categorical covariates showed association at the 1% level ($p > 0.01$) except for Fuchs endothelial dystrophy ($p = 0.052$), inherited eye disease ($p = 0.040$), oculomotor disease ($p = 0.068$) and other macular pathology ($p = 0.943$). For continuous covariates, univariate analysis did not show any association for ACD ($p = 0.440$) (Table 1).

Table 1
Univariate analysis for covariates under consideration for the PCR risk factor modelling. The PCR rate for the continuous covariates is the overall PCR rate for the sample. N = 961 208 cataract operations performed in 136 centres by 3 198 surgeons.

PCR risk factor model covariates univariate analysis	No PCR	PCR	Total	PCR %	p-value
Number of operations	951 478	9 730	961 208	1.01	N/A
Surgical factors					
Surgeon grade					
Consultant surgeon	732 857	5 670	738 527	0.77	< 0.001
Career grade non-consultant surgeon	56 908	721	57 629	1.25	
More experienced trainee surgeon	138 728	2 724	141 452	1.93	
Less experienced trainee surgeon	22 985	615	23 600	2.61	
Patient factors					
Age at surgery (year)					
Mean	74.52	75.00	74.52	1.01	< 0.001
Standard deviation	9.81	10.65	9.82		
Gender					
Female	551 736	5 154	556 890	0.93	< 0.001
Male	399 742	4 576	404 318	1.13	
Ability to lie flat and cooperate					
Yes	919 597	9 312	928 909	1.00	< 0.001
No	31 881	418	32 299	1.29	
Systemic diabetes					
No	807 527	7 577	815 104	0.93	< 0.001
Yes	143 951	2 153	146 104	1.47	
Ocular factors					
First or second treated eye*					
First	563 894	6 160	570 054	1.08	< 0.001
Second	387 584	3 570	391 154	0.91	
Previous intravitreal anti-VEGF therapy					
No	929 424	9 239	938 663	0.98	< 0.001
Yes	22 054	491	22 545	2.18	
Pupil size					
Small	51 309	928	52 237	1.78	< 0.001
Medium	277 382	2 967	280 349	1.06	
Large	595 129	5 533	600 662	0.92	
*First treated eye surgery includes both eyes from ISBCS patients					

PCR risk factor model covariates univariate analysis	No PCR	PCR	Total	PCR %	p-value
Not recorded	27 658	302	27 960	1.08	
Anterior chamber depth (mm)					
Mean	3.08	3.08	3.08	1.01	0.440
Standard deviation	0.42	0.46	0.42		
Preoperative visual acuity (LogMAR)					
Mean	0.59	0.82	0.60	1.01	< 0.001
Standard deviation	0.50	0.68	0.50		
Ocular comorbidities					
Age-related macular degeneration					
No	853 235	8 632	861 867	1.00	0.002
Yes	98 243	1 098	99 341	1.11	
Amblyopia					
No	936 791	9 502	946 293	1.00	< 0.001
Yes	14 687	228	14 915	1.53	
Brunescent / white / mature cataract					
No	900 525	8 164	908 689	0.90	< 0.001
Yes	50 953	1 566	52 519	2.99	
Corneal pathology					
No	882 269	9 209	891 478	1.03	< 0.001
Yes	69 209	521	69 730	0.75	
Diabetic retinopathy					
No	902 058	8 864	910 922	0.97	< 0.001
Yes	49 420	866	50 286	1.72	
Fuchs endothelial dystrophy					
No	949 186	9 716	958 902	1.01	0.052
Yes	2 292	14	2 306	0.61	
Glaucoma					
No	864 599	8 147	872 746	0.93	< 0.001
Yes	86 879	1 583	88 462	1.79	
High myopia					
No	920 242	9 310	929 552	1.00	< 0.001
Yes	31 236	420	31 656	1.33	
Inherited eye disease					
No	945 734	9 687	955 421	1.01	0.040
*First treated eye surgery includes both eyes from ISBCS patients					

PCR risk factor model covariates univariate analysis	No PCR	PCR	Total	PCR %	p-value
Yes	5 744	43	5 787	0.74	
No fundal view / vitreous opacity					
No	925 708	9 096	934 804	0.97	< 0.001
Yes	25 770	634	26 404	2.40	
Oculomotor disease					
No	949 782	9 705	959 487	1.01	0.068
Yes	1 696	25	1 721	1.45	
Other macular pathology					
No	914 577	9 354	923 931	1.01	0.943
Yes	36 901	376	37 277	1.01	
Other retinal vascular pathology					
No	942 729	9 583	952 312	1.01	< 0.001
Yes	8 749	147	8 896	1.65	
Previous trabeculectomy					
No	948 226	9 678	957 904	1.01	0.001
Yes	3 252	52	3 304	1.57	
Previous vitrectomy					
No	936 330	9 473	945 803	1.00	< 0.001
Yes	15 148	257	15 405	1.67	
Pseudoexfoliation / phacodonesis					
No	943 449	9 322	952 771	0.98	< 0.001
Yes	8 029	408	8 437	4.84	
Uveitis / synechiae					
No	945 760	9 647	955 407	1.01	0.001
Yes	5 718	83	5 801	1.43	
*First treated eye surgery includes both eyes from ISBCS patients					

During the risk factor model fitting process, the following covariates were removed due to no association at the 1% level ($p > 0.01$); age-related macular degeneration, no fundal view / vitreous opacity, other retinal vascular pathology, previous trabeculectomy surgery and uveitis / synechiae. Both amblyopia and corneal pathology implied association between the 0.1% and 1% level ($p > 0.001$ & $p < 0.01$). Removing amblyopia did not improve the model fit and was retained. A similar finding was seen for corneal pathology but a decision was made to not include this due to the implied protective effect from its presence, and also because there can be large variation in why a surgeon would record this (e.g. a small peripheral scar or full thickness central opacity).

The final model included the following surgical and patient factors: surgeon grade, patients' age and gender, ability to lie flat and cooperate, diabetic status and an interaction term between age and gender. Ocular factors were first or second eye surgery, ACD, preoperative VA, previous intravitreal anti-vascular endothelial growth factor (VEGF) therapy, pupil size, amblyopia, brunescent /

white / mature cataract, diabetic retinopathy, glaucoma, high myopia, previous vitrectomy surgery and pseudoexfoliation / phacodonesis (Table 2).

Table 2
Final PCR risk factor model estimates. N = 961 208 cataract operations performed in 136 centres by 3 198 surgeons.

PCR risk factor model covariates	Odds ratio	Coefficient	Standard error	p-value	95% confidence interval for odds ratio
Constant	0.002	-6.391	< 0.001	< 0.001	0.001 to 0.002
Surgical factors					
Surgeon grade					
Consultant surgeon	REF	REF	N/A	N/A	N/A
Career grade non-consultant surgeon	1.586	0.461	0.164	< 0.001	1.294 to 1.943
More experienced trainee surgeon	2.484	0.910	0.100	< 0.001	2.296 to 2.688
Less experienced trainee surgeon	3.754	1.323	0.231	< 0.001	3.328 to 4.235
Patient factors					
Age at surgery (year)	1.015	0.015	0.002	< 0.001	1.012 to 1.018
Gender					
Female	REF	REF	N/A	N/A	N/A
Male	3.046	1.114	0.485	< 0.001	2.229 to 4.162
Gender and age interaction*	0.987	-0.013	0.002	< 0.001	0.983 to 0.991
Ability to lie flat and cooperate					
Yes	REF	REF	N/A	N/A	N/A
No	1.186	0.171	0.063	0.001	1.069 to 1.317
Systemic diabetes					
No	REF	REF	N/A	N/A	N/A
Yes	1.239	0.215	0.043	< 0.001	1.157 to 1.327
Ocular factors					
First or second treated eye					
First	REF	REF	N/A	N/A	N/A
Second	0.904	-0.101	0.019	< 0.001	0.868 to 0.942
Previous intravitreal anti-VEGF therapy					
No	REF	REF	N/A	N/A	N/A
Yes	1.427	0.356	0.075	<	1.287 to 1.582

*For the gender and age interaction, the reference would be female patients

**For all ocular comorbidities, the reference category is absence of the condition (i.e., eyes without the condition)

PCR risk factor model covariates	Odds ratio	Coefficient	Standard error	p-value	95% confidence interval for odds ratio
				0.001	
Pupil size					
Small	REF	REF	N/A	N/A	N/A
Medium	0.655	-0.424	0.032	< 0.001	0.596 to 0.720
Large	0.648	-0.434	0.027	< 0.001	0.596 to 0.703
Not recorded	0.657	-0.420	0.059	< 0.001	0.550 to 0.783
Anterior chamber depth (mm)	1.113	0.107	0.033	< 0.001	1.051 to 1.178
Preoperative visual acuity (LogMAR)	1.510	0.412	0.028	< 0.001	1.457 to 1.566
Ocular comorbidities**					
Amblyopia	1.205	0.187	0.083	0.007	1.052 to 1.380
Brunescent / white / mature cataract	2.409	0.879	0.092	< 0.001	2.236 to 2.595
Diabetic retinopathy	1.176	0.162	0.058	0.001	1.068 to 1.294
Glaucoma	1.713	0.538	0.074	< 0.001	1.574 to 1.863
High myopia	1.395	0.333	0.075	< 0.001	1.256 to 1.550
Previous vitrectomy	1.241	0.216	0.084	0.001	1.086 to 1.417
Pseudoexfoliation / phacodonesis	3.466	1.243	0.228	< 0.001	3.048 to 3.942
*For the gender and age interaction, the reference would be female patients					
**For all ocular comorbidities, the reference category is absence of the condition (i.e., eyes without the condition)					

The final model had an area under the receiver curve estimate of 70.0%. The highest influencing risk factors were surgery by less experienced trainee surgeon and pseudoexfoliation / phacodonesis, where the odds ratios were > 3 (Supplementary Figure), as was the case for male gender but this large odds ratio is mitigated by the age/gender interaction which reduces the risk for a male patient according to his age, where the older a male patient is, the lower his PCR risk is compared to that of a female patient of the same age (Fig. 1). Certain identified risk factors such as systemic diabetes, diabetic retinopathy, small pupil and previous vitrectomy were more prevalent in male than female patients (Supplementary Table).

The underlying risk of PCR for preoperative VA follows a near linear progression where worse levels of VA have a higher risk of PCR (Fig. 2). For ACD, the underlying risk of PCR is higher for eyes with a shallow AC (< 2.2mm) (Fig. 3). For the continuous covariates, interpretation of the odds ratios is such that a one-unit change alters the odds by the percentage the ratio implies. For example, each one-year increase in age leads to a 1.5% increase in the age odds whereas each 1.00 LogMAR increase leads to a 51.0% increase in the VA odds (0.10 LogMAR increase leads to a 5.1% increase in the VA odds).

Risk of PCR examples

An example for first eye surgery performed by a consultant surgeon on an 80-year-old female patient who can lie flat and cooperate with systemic diabetes, median ACD of 3.08mm, median preoperative VA of 0.50 LogMAR, a large pupil, no previous

intravitreal anti-VEGF therapy, and none of the ocular comorbidities, the estimated probability of PCR is 0.77%. If the surgery had been performed by a less experienced trainee the estimated probability is 2.82%. For a male patient with the same age and ocular characteristics, the estimated probability of PCR is 0.82% when surgery was performed by a consultant surgeon, and 3.02% when performed by a less experienced trainee surgeon. Conversely, the estimated probability of PCR is 0.42% for a 40-year-old female patient operated on by a consultant, compared to 0.76% for a 40-year-old male patient with the same ocular characteristics.

Discussion

The current analysis covers the 2016–2021 NHS years and includes the largest national sample size to date. The selected time period coincides with the period operations have been performed with access to annual national benchmarks published by the RCOphth NOD, increasing use of surgical simulators in training and growing provision of surgery by the independent sector.

In addition to providing an update to the current statistical model for case complexity adjustment, the current analysis has confirmed previously known risk factors for PCR (advancing age, junior surgeon, male gender, inability to lie flat and cooperate, systemic diabetes, diabetic retinopathy, smaller pupil size, mature cataract, glaucoma and pseudoexfoliation / phacodonesis), corroborated more recently reported risk factors (previous intravitreal anti-VEGF therapy[23,27,28] and worse preoperative VA[24]) and quantified the impact of additional risk factors (high myopia, previous vitrectomy, shallow ACD and amblyopia).

Of particular note compared to the previous UK Cataract National Dataset analysis, the elevated odds ratio for PCR observed for younger male patients was found to be one of the highest with an adjusted odds ratio of 3.05, however the age/gender interaction term diminishes this ratio in older patients such that there is parity of risk between the genders by age 85, and above 90 years of age females are seen to be at a higher risk of PCR (Fig. 1). The inclusion of the interaction term is an attempt to account for the differences across the age range, and assessment of different risks between male and female patients has to be considered in relation to the patients' age. The reasons for these differences are likely to be complex and postulated contributing factors may include greater lifetime accumulation of ocular trauma[29] and less willingness to engage with healthcare services[30] within younger males. Some of the identified risk factors in this analysis were also more prevalent in male than female patients, although other identified risk factors were more prevalent in female patients, consequently these differences cannot account for all of the observed higher risk for male gender (Supplementary Table).

Our finding of prior intravitreal anti-VEGF injections being associated with increased risk of PCR is consistent with previous studies[23,27,28]. There is currently evidence to suggest that the risk of PCR is dose-dependent and higher for eyes that have received > 10 injections[23,28]. However, in our analysis, we were not able to specifically look at the number of prior intravitreal injections so there may be some underestimation of effect.

We also found preoperative high myopia to be a significant risk factor for PCR. This is somewhat expected based on prior studies suggesting greater risk of intraoperative complications during phacoemulsification[31,32]. One theorised mechanism for this is the longer AL inherent in these eyes which may make surgery more challenging. However, previous analyses have found no significant association between AL and risk of PCR[2,8], which would suggest other possible contributory mechanisms in high myopia such as higher cataract density[33].

Previous studies on the risk of intraoperative complications in eyes with prior pars plana vitrectomy (PPV) have reported mixed findings[24,34]. We found a significantly higher rate of PCR in eyes with previous PPV which could be conferred by altered fluid dynamics[35], unstable posterior capsules[36] or posterior lenticular touch during vitrectomy[37]. The pathophysiology underlying the increased risk of PCR in vitrectomised eyes may also have some overlap with that of high myopia given the strong correlation between the two[38].

Similar to previous PPV, there is currently no consensus on whether shallow ACD increases the risk of PCR[39–41]. We found that a shallow ACD of < 2.2mm was associated with a significant increase in PCR rates. One possible explanation for this may be that

iris prolapse is more common so surgeons make longer tunnels, increasing corneal distortion and impairing visualisation, or more directly increasing proximity of surgical instruments to the posterior capsule in a shallow anterior chamber.

The increased risk of PCR in patients with worse preoperative VA is likely due to the denser nature of cataracts and the inherent intraoperative challenges associated with this (e.g. poor visualisation, higher incidence of zonular pathology). A similar explanation could also apply for amblyopia as there is often, and perhaps inappropriately, delay in cataract surgery leading to a denser cataract[42].

In contrast to the recent European registry analysis which found corneal opacities to be the most significantly associated risk factor for PCR[24], we found a protective effect of corneal pathology against PCR. The interpretation of this discrepancy is compounded and limited by the heterogeneity in definition of “corneal opacities” and “corneal pathology” which includes a broad spectrum of phenotype. Nonetheless, one possible explanation for the protective effect of corneal pathology is that there might be a lower threshold for earlier (and hence easier) cataract surgery in affected eyes due to their worse baseline vision.

This study has several limitations. In this analysis, 40.8% patients had bilateral cataract surgery which can introduce patient level correlation impacting on statistical comparisons. Attempting to account for potential patient level correlation was not part of the model fitting, instead cluster adjustment for robust standard errors focussed on the operating surgeon, by considering their operations in different centres and for different surgeon grades as separate clusters. This attempted to account for surgeons with different responsibilities and experience over the study period, and them working with different theatre teams and in different hospitals. The decision was made to consider surgeons as clusters instead of patients, as patients will have at most two operations, whereas surgeons can operate on thousands of patients. Furthermore, some ocular diseases can develop as bilateral disease, and some are linked to age and be more prevalent in second treated eyes.

It is possible that not all recorded first treated eye operations were patients’ actual first eye surgery, as patients could have their first eye surgery prior to a centre adopting an EMR, or performed in a different centre, and at present the audit cannot link patients’ data if collected at different centres. It was also not possible to separate pseudoexfoliation and phacodonesis to fit as individual terms in the modelling due to the current option to record both as a combined term on the EMR systems.

Potentially influencing risk factors that were not considered were AL and social deprivation. AL was not considered as it is correlated with ACD and previous studies have shown that AL is not a significant influencer for PCR risk[2,8]. Social deprivation was not considered because the audit did not receive this information from all contributing centres due to the differing data collection systems used, and that there are different indices for the different UK nations.

The PCR risk factor model was not a perfect fit, the area under the operating receiver curve value of 70.0% implies there is unaccounted for variation, and the number of significant covariates is a concern regarding possible overfitting, although this is also a reflection of the various clinical factors that can influence the risk of PCR and is linked to a large sample with many covariates having low event rates. Consequently, the interpretation of p-values require caution as they are likely to be too low, especially for covariates with extremely low event rates.

In summary, this analysis provides an update to the current risk adjustment model for PCR with the quantification of additional risk factors. This will facilitate a bespoke, contemporary risk assessment tailored to an individual patient’s operation, thereby allowing more informed patient counselling, appropriate case allocation and adoption of precautionary measures to minimise the risk of PCR during surgery.

Declarations

Acknowledgements

We acknowledge with thanks the contribution of Professor John Sparrow who provided diligent clinical and academic oversight and leadership of the RCOphth NOD over many years to bring it to its current stature. It is with gratitude that we remember our friend and colleague Robert Johnston, who sadly died in September 2016. Without his inspirational vision, determination and career long commitment to quality improvement in ophthalmology, this work would not have been possible.

We acknowledge the support of the hospitals that participated in this National Ophthalmology Database Audit study and thank our medical and non-medical colleagues for the considerable time and effort devoted to conscientious electronic data collection as they go about caring for their patients.

The full list of the 136 participating centres included in this study is detailed in Supplementary File.

Conflict of Interest: All authors declare no conflict of interest.

Funding: The RCOphth National Ophthalmology Database Cataract Audit is currently funded through participation fees from centres as well as unrestricted financial contributions from Alcon and Bausch and Lomb. This research was supported by the NIHR Moorfields Clinical Research Facility and NIHR Biomedical Research Centre at Moorfields Eye Hospital and UCL Institute of Ophthalmology.

Author Contribution

PYS, PHJD, ACD and JCB conceptualised the study. PHJD prepared the study data and performed the statistical analysis. All authors contributed to interpretation of the results. PYS and PHD wrote the first draft of the manuscript. All authors contributed to critical revision of the manuscript and approved the final manuscript. JCB is the overall content guarantor.

References

1. Day AC, Donachie PHJ, Sparrow JM, Johnston RL. The Royal College of Ophthalmologists' National Ophthalmology Database study of cataract surgery: report 1, visual outcomes and complications. Eye. 2015; 29(4): 552–560.
2. Day AC, Donachie PHJ, Sparrow JM, Johnston RL. The Royal College of Ophthalmologists' National Ophthalmology Database Study of cataract surgery: report 2, relationships of axial length with ocular copathology, preoperative visual acuity, and posterior capsule rupture. Eye. 2015; 29(12): 1528–1537.
3. Day AC, Donachie PHJ, Sparrow JM, Johnston RL. United Kingdom National Ophthalmology Database Study of Cataract Surgery: Report 3: Pseudophakic Retinal Detachment. Ophthalmology. 2016; 123(8): 1711–1715.
4. Johnston RL, Day AC, Donachie PHJ, Sparrow JM. The Royal College of Ophthalmologists' National Ophthalmology Database study of cataract surgery: report 4, equity of access to cataract surgery. Eye. 2020; 34(3): 530–536.
5. Theodoropoulou S, Grzeda MT, Donachie PHJ, Johnston RL, Sparrow JM, Tole DM. The Royal College of Ophthalmologists' National Ophthalmology Database Study of cataract surgery. Report 5: Clinical outcome and risk factors for posterior capsule rupture and visual acuity loss following cataract surgery in patients aged 90 years and old. Eye. 2019; 33(7): 1161–1170.
6. Ferris JD, Donachie PH, Johnston RL, Barnes B, Olaitan M, Sparrow JM. Royal College of Ophthalmologists' National Ophthalmology Database study of cataract surgery: report 6. The impact of EyeSi virtual reality training on complications rates of cataract surgery performed by first and second year trainees. Br. J. Ophthalmol. 2020; 104(3): 324–329.
7. Buchan JC, Donachie PHJ, Cassels-Brown A, Liu C, Pyott A, Yip JLY, et al. The Royal College of Ophthalmologists' National Ophthalmology Database study of cataract surgery: Report 7, immediate sequential bilateral cataract surgery in the UK: Current practice and patient selection. Eye. 2020; 34(10): 1866–1874.
8. Day AC, Norridge CFE, Donachie PHJ, Barnes B, Sparrow JM. Royal College of Ophthalmologists' National Ophthalmology Database study of cataract surgery: report 8, cohort analysis of the relationship between intraoperative complications of cataract surgery and axial length. BMJ Open. 2022; 12(8): e053560.
9. Donachie PHJ, Barnes BL, Olaitan M, Sparrow JM, Buchan JC. The Royal College of Ophthalmologists' National Ophthalmology Database study of cataract surgery: Report 9, Risk factors for posterior capsule opacification. Eye. 2023; 37: 1633–1639.
10. Low L, Shah V, Norridge CFE, Donachie PHJ, Buchan JC. RCOphth NOD, Report 10: Risk factors for post-cataract surgery endophthalmitis. Ophthalmology. 2023; 130(11): 1228-1230.

11. Neo YN, Gruszka-Goh MH, Braga AJ, de Klerk TA, Lindfield D, Nestel A, et al. The Royal College of Ophthalmologists' National Ophthalmology Database Study of Cataract Surgery: report 11, Techniques and Complications of Local Anaesthesia for Cataract Surgery in the United Kingdom. J. Cataract Refract. Surg. 2023; 49(12): 1216-1222.
12. Stewart S, Gruszka-Goh MH, Neo YN, Braga AJ, de Klerk TA, Lindfield D, et al. The Royal College of Ophthalmologists' National Ophthalmology Database Study of Cataract Surgery: Report 12, Risk factors for suprachoroidal haemorrhage during cataract surgery. Eye. 2023; 37(9): 1778–1787.
13. Ting DSJ, Tatham AJ, Donachie PHJ, Buchan JC. The Royal College of Ophthalmologists' National Ophthalmology Database study of cataract surgery: report 16, influence of remuneration model on choice of intraocular lens in the UK. Eye. 2023; 37(18): 3854-3860.
14. Sparrow JM, Taylor H, Qureshi K, Smith R, Birnie K, Johnston RL, et al. The Cataract National Dataset electronic multi-centre audit of 55 567 operations: risk indicators for monocular visual acuity outcomes. Eye. 2012; 26(6): 821–826.
15. Chu CJ, Johnston RL, Buscombe C, Sallam AB, Mohamed Q, Yang YC. Risk Factors and Incidence of Macular Edema after Cataract Surgery: A Database Study of 81984 Eyes. Ophthalmology. 2016; 123(2): 316–323.
16. Qatarneh D, Mathew RG, Palmer S, Bunce C, Tuft S. The economic cost of posterior capsule tear at cataract surgery. Br. J. Ophthalmol. 2012; 96(1): 114–117.
17. Ryburn C, Patnaik JL, Miller DC, Alexander J, Lynch AM, Davidson RS, et al. What Is the Cost of a Posterior Capsule Rupture Complication? Ophthalmic Surgery, Lasers Imaging Retin. 2020; 51(8): 444–447.
18. Narendran N, Jaycock P, Johnston RL, Taylor H, Adams M, Tole DM, et al. The Cataract National Dataset electronic multicentre audit of 55 567 operations: risk stratification for posterior capsule rupture and vitreous loss. Eye. 2009; 23(1): 31–37.
19. The Royal College of Ophthalmologists. National Ophthalmology Database Audit: Year 1 Annual Report - Piloting of the National Ophthalmology Database Audit Methodology. 2016. Available at: https://nodaudit.org.uk/sites/default/files/2022-06/Annual%20Report%202016%20%20Year%201%20Piloting%20of%20the%20National%20Ophthalmology%20Database.pdf
20. The Royal College of Ophthalmologists. National Ophthalmology Database Audit: Year 7 Annual Report - The Sixth Prospective Report of the National Ophthalmology Database Audit National Cataract Audit. 2023. Available at: https://nodaudit.org.uk/sites/default/files/2023-08/NOD Cataract Audit Full Annual Report 2023.pdf.
21. Maubon LG, Ursell PG. Reduced posterior capsular rupture rate observed among trainee surgeons utilizing a disposable silicone-tipped irrigation and aspiration handpiece for soft lens removal. Expert Rev. Ophthalmol. 2018; 13(5): 293–297.
22. Lundström M, Dickman M, Henry Y, Manning S, Rosen P, Tassignon M-J, et al. Changing practice patterns in European cataract surgery as reflected in the European Registry of Quality Outcomes for Cataract and Refractive Surgery 2008 to 2017. J. Cataract Refract. Surg. 2021; 47(3): 373-378
23. Lee AY, Day AC, Egan C, Bailey C, Johnston RL, Tsaloumas MD, et al. Previous Intravitreal Therapy Is Associated with Increased Risk of Posterior Capsule Rupture during Cataract Surgery. Ophthalmology. 2016; 123(6): 1252–1256.
24. Segers MHM, Behndig A, van den Biggelaar FJHM, Brocato L, Henry YP, Nuijts RMMA, et al. Risk factors for posterior capsule rupture in cataract surgery as reflected in the European Registry of Quality Outcomes for Cataract and Refractive Surgery. J. Cataract Refract. Surg. 2022; 48(1): 51-55.
25. Salowi MA, Chew FLM, Adnan TH, King C, Ismail M, Goh P-P. The Malaysian Cataract Surgery Registry: risk Indicators for posterior capsular rupture. Br. J. Ophthalmol. 2017; 101(11): 1466–1470.
26. Moussa G, Bassilious K, Mathews N. A novel excel sheet conversion tool from Snellen fraction to LogMAR including 'counting fingers', 'hand movement', 'light perception' and 'no light perception' and focused review of literature of low visual acuity reference values. Acta Ophthalmol. 2021; 99(6): e963–e965.
27. Shalchi Z, Okada M, Whiting C, Hamilton R. Risk of Posterior Capsule Rupture During Cataract Surgery in Eyes With Previous Intravitreal Injections. Am. J. Ophthalmol. 2017; 177: 77–80.
28. Nagar AM, Luis J, Kainth N, Panos GD, Mckechnie CJ, Patra S. The Risk of Posterior Capsule Rupture during Phacoemulsification Cataract Surgery in Eyes with Previous Intravitreal Anti Vascular Endothelial Growth Factor Injections. J. Cataract Refract. Surg. 2020; 46(2): 204-208.

29. Serna-Ojeda JC, Cordova-Cervantes J, Lopez-Salas M, Abdala-Figuerola AC, Jimenez-Corona A, Matiz-Moreno H, et al. Management of traumatic cataract in adults at a reference center in Mexico City. Int. Ophthalmol. 2015; 35(4): 451–458.
30. Wang Y, Hunt K, Nazareth I, Freemantle N, Petersen I. Do men consult less than women? An analysis of routinely collected UK general practice data. BMJ Open. 2013; 3(8): e003320.
31. Zuberbuhler B, Seyedian M, Tuft S. Phacoemulsification in eyes with extreme axial myopia. J. Cataract Refract. Surg. 2009; 35(2): 335-340.
32. Yao Y, Lu Q, Wei L, Cheng K, Lu Y, Zhu X. Efficacy and complications of cataract surgery in high myopia. J. Cataract Refract. Surg. 2021; 47(11): 1473-1480.
33. Praveen MR, Vasavada AR, Jani UD, Trivedi RH, Choudhary PK. Prevalence of Cataract Type in Relation to Axial Length in Subjects with High Myopia and Emmetropia in an Indian Population. Am. J. Ophthalmol. 2008; 145(1): 176-181.
34. Mudie LI, Patnaik JL, Lynch AM, Wise RE. Prior pars plana vitrectomy and its association with adverse intraoperative events during cataract surgery. Acta Ophthalmol. 2022; 100(2): e423–e429.
35. Ahfat FG, Yuen CHW, Groenewald CP. Phacoemulsification and intraocular lens implantation following pars plana vitrectomy: a prospective study. Eye. 2003; 17(1): 16–20.
36. Lee JY, Kim K-H, Shin KH, Han DH, Lee DY, Nam DH. Comparison of intraoperative complications of phacoemulsification between sequential and combined procedures of pars plana vitrectomy and cataract surgery. Retina. 2012; 32(10): 2026-2033.
37. Asaria RHY, Wong SC, Sullivan PM. Risk for posterior capsule rupture after vitreoretinal surgery. J. Cataract Refract. Surg. 2006; 32(6): 1068-1069.
38. Coppola M, Rabiolo A, Cicinelli MV, Querques G, Bandello F. Vitrectomy in high myopia: a narrative review. Int. J. Retin. Vitr. 2017; 3(1): 37.
39. Chen M, LaMattina KC, Patrianakos T, Dwarakanathan S. Complication rate of posterior capsule rupture with vitreous loss during phacoemulsification at a Hawaiian cataract surgical center: A clinical audit. Clin. Ophthalmol. 2014; 8: 375–378.
40. Küchle M, Viestenz A, Martus P, Händel A, Jünemann A, Naumann GOH. Anterior chamber depth and complications during cataract surgery in eyes with pseudoexfoliation syndrome. Am. J. Ophthalmol. 2000; 129(3): 281–285.
41. Blomquist PH, Morales ME, Tong L, Ahn C. Risk factors for vitreous complications in resident-performed phacoemulsification surgery. J. Cataract Refract. Surg. 2012; 38(2): 208-214.
42. Harrad RA, Tole D, Waterfall J. The Outcome of Cataract Surgery in Amblyopia. Invest. Ophthalmol. Vis. Sci. 2008; 49(13): 2831.

Figures

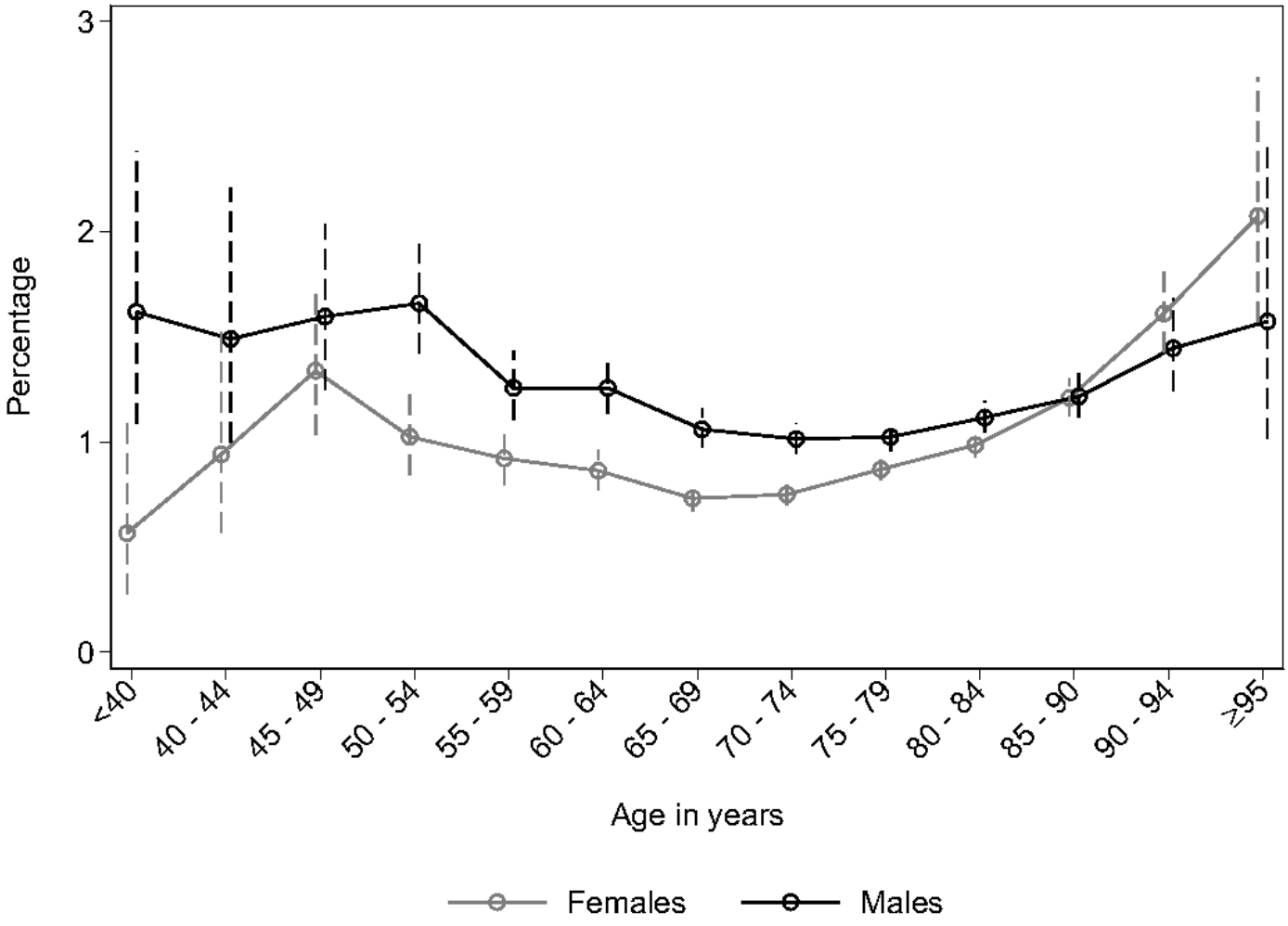


Figure 1

Observed PCR rates for patients' age and gender displayed in 5-year age bandings. N = 961 208 cataract operations performed in 136 centres by 3 198 surgeons. 95% confidence intervals derived using the Fliess quadratic continuity correction. Estimates plotted at the boundary -0.25 for females and +0.25 for males for display purposes.

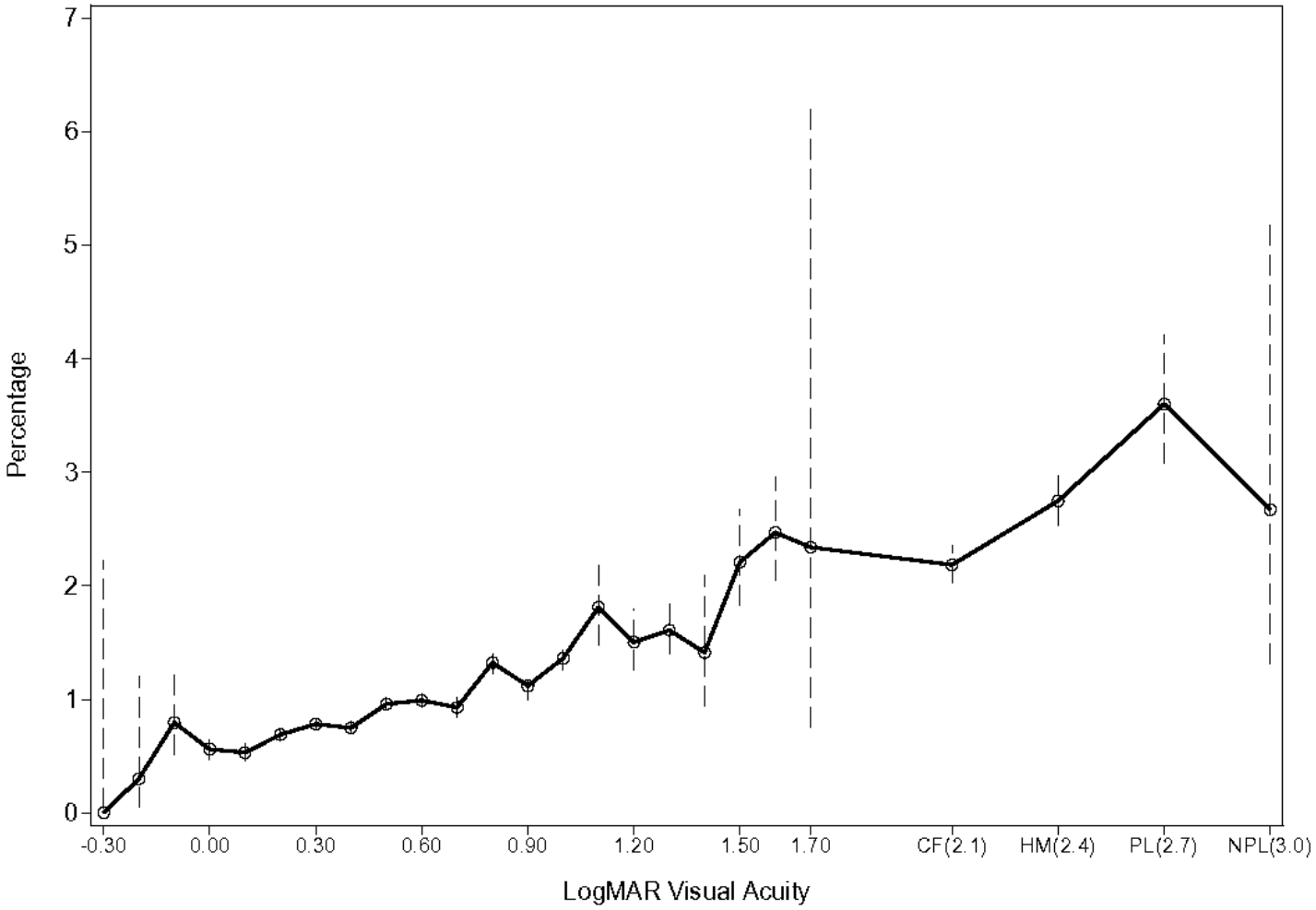


Figure 2

Observed PCR rates for preoperative LogMAR visual acuity displayed in 0.10 LogMAR bandings. N = 961 208 cataract operations performed in 136 centres by 3 198 surgeons. 95% confidence intervals derived using the Fliess quadratic continuity correction.

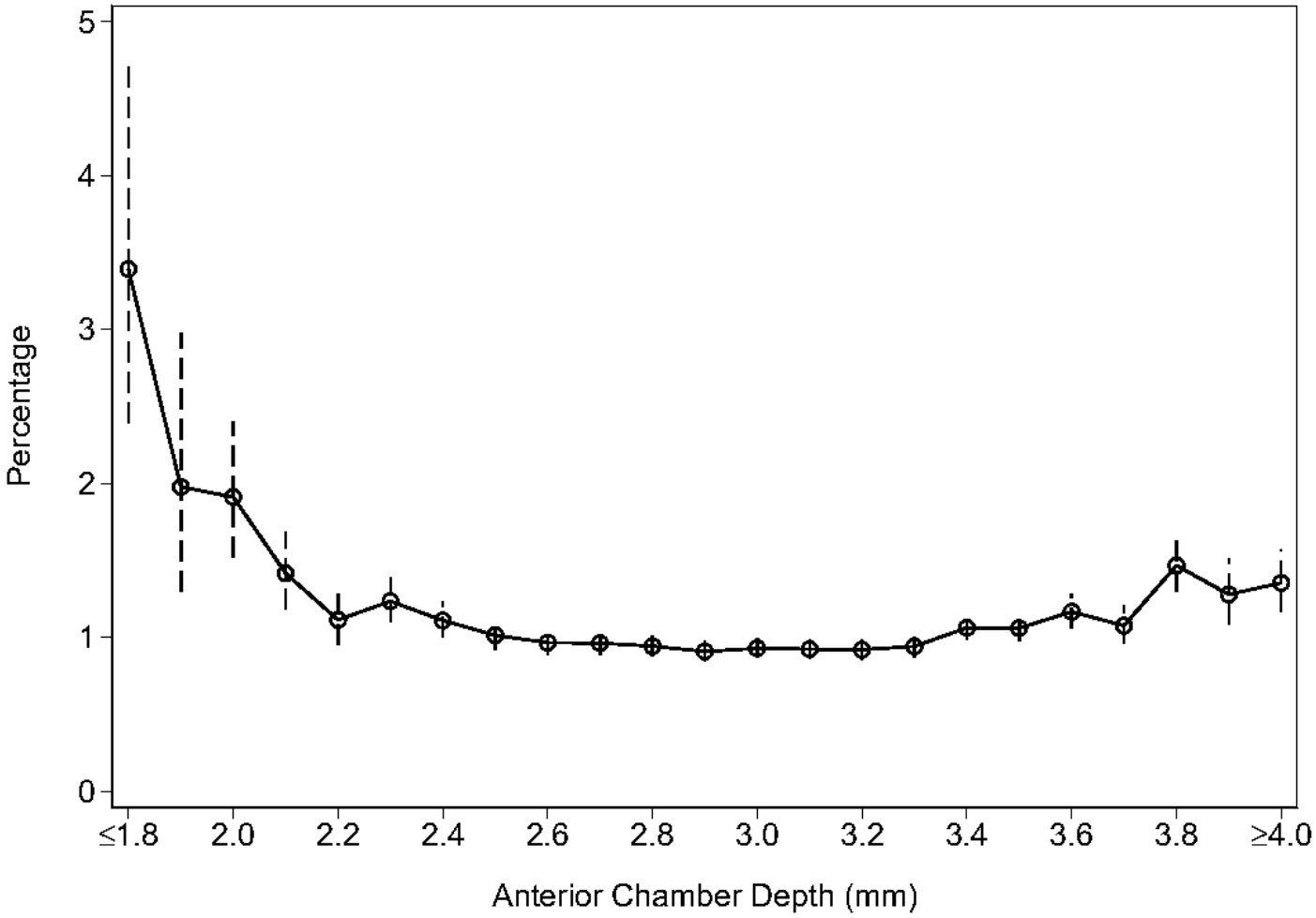


Figure 3

Observed PCR rates for anterior chamber depth displayed in 0.1 mm increments. N = 961 208 cataract operations performed in 136 centres by 3 198 surgeons. 95% confidence intervals derived using the Fliess quadratic continuity correction.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryFigure.pdf
- SupplementaryFile1.docx
- SupplementaryFile2.docx
- SupplementaryTable.docx