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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

AC Day, PHJ Donachie, JM Sparrow and RL Johnston on behalf of all surgeons contributing towards The Royal College of Ophthalmologists' National Ophthalmology Database

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Learning Objectives

Upon completion of this activity, participants will be able to:

1. Assess the relationship between axial length and different forms of ocular pathology.
2. Distinguish any association between axial length and the presence of brunescent or white cataracts.
3. Determine how axial length might affect visual acuity before cataract surgery.
4. Evaluate the effect of axial length on posterior capsule rupture, vitreous loss, or both among patients undergoing cataract surgery.

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CLINICAL STUDY

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

AC Day[1], PH J Donachie[2,3], JM Sparrow[2,4] and RL Johnston[2,3] on behalf of all surgeons contributing towards The Royal College of Ophthalmologists' National Ophthalmology Database

Abstract

Purpose **To describe the relationships of axial length with ocular copathology, preoperative visual acuity, and posterior capsule rupture rates in patients undergoing cataract surgery.**

Design **The Royal College of Ophthalmologists' National Ophthalmology Database (NOD) study.**

Methods **Anonymised data on 180 114 eyes from 127 685 patients undergoing cataract surgery between August 2006 and November 2010 were collected prospectively from 28 sites. Data parameters included: demographics, biometry, ocular copathology, visual acuity measurements, and surgical complications including posterior capsule rupture, or vitreous loss or both (PCR).**

Results **Consultant surgeons performed a higher proportion of operations on eyes whose axial length were at the extremes. Glaucoma and age related macular degeneration were more common in eyes with shorter axial lengths, whilst previous vitrectomy was associated with longer axial lengths. Eyes with brunescent or white cataracts or amblyopia were more common at both axial length extremes. Preoperative visual acuities were similar for eyes with axial length measurements up to approximately 28 mm and worse for eyes with longer axial length measurements. PCR rates showed little change with axial length (overall mean 1.95%, 95% CI: 1.89 to 2.01%), except for a borderline increase in eyes with axial length <20.0 mm where rates were 3.6% (95% CI: 2.0 to 6.3%). The likelihood of PCR in eyes with axial length <20.0 mm was 1.88 times higher than those of ≥ 20.0 mm ($P = 0.0373$).**

Conclusion **Rates of ocular comorbidities vary by axial length. PCR rates in eyes with very short or long axial lengths were lower than expected.**

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Introduction

The Royal College of Ophthalmologists' National Ophthalmology Database (RCOphth NOD) was established to provide national audit and research data, and to provide an evidence base for revalidation standards allowing ophthalmologists to compare their surgical outcomes with those of their anonymised peers. The RCOphth NOD is the formalised successor to the *ad hoc* collaboration that resulted in the Cataract National Dataset publications.[1–5] The RCOphth NOD covers a range of conditions and operations.[6–9] RCOphth NOD data on cataract

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surgery complication rates, visual outcomes, and proportions with ocular copathology have already been reported.[10] This found visual outcomes, and the rate of posterior capsule rupture or vitreous loss or both appeared stable when compared with the previous Cataract National Data set analysis that used data from 2001 to 2006.[1] The aims of this analysis are to investigate for differences in ocular co-pathology rates, preoperative visual acuity and posterior capsule rupture rates by ocular axial length.

Materials and methods

Data were extracted from 31 UK National Health Service (NHS) Trusts of which 27 had recorded data for cataract surgery on the same electronic medical record (EMR) system (Medisoft Ophthalmology, Medisoft Limited, Leeds, UK) for cataract operations performed between August 2006 and November 2010. The lead clinician and Caldicott Guardian (responsible nominee for data protection) at each NHS Trust gave written approval for anonymised data extraction. Anonymised database analyses of this type do not require ethical permission as they are viewed as audit or service evaluation (see http://www.hra.nhs.uk/research-community/before-you-apply/determine-whether-your-study-is-research/) and this was confirmed by a Research Ethics Committee. This study was conducted in accordance with the declaration of Helsinki, and the UK's Data Protection Act.

Case definitions

Eligible cataract operations were those performed on patients aged 18 years or older using phacoemulsification and where the primary intention was cataract surgery and not combined 'cataract+other' surgery. Eyes with missing baseline axial length or a baseline axial length measurement of <15 mm were excluded from the analysis. Surgeon grades were categorised as: Consultant surgeons, independent non-consultant surgeons (staff grades, associate specialists and Trust doctors) and trainee surgeons (fellows and Specialist Registrars, SHOs, Specialist Trainees and Foundation Year doctors). Owing to the progression through training an individual surgeon can have data recorded for more than one grade.

Ocular copathology

Recording the absence or presence of one or more ocular co-pathologies (reasons for a guarded visual prognosis) from a limited list is a compulsory field within the operation screen of the EMR as defined in the UK Cataract National Data set (see https://www.rcophth.ac.uk/standards-publications-research/clinical-data-sets/cataract-national-data-set/). Ocular copathologies are categorised as: corneal pathology, glaucoma, uveitis, pseudoexfoliation, vitreous opacification, diabetic retinopathy, age-related macular degeneration (AMD), high myopia, other macular pathology, retinal vascular occlusion, previous vitreoretinal procedures, no view of the fundus, optic nerve or CNS degeneration, and amblyopia in the operated eye. An 'other' option allows clinicians to use free text to record co-pathologies that are not covered by the limited list and high myopia was not included in this analysis as it is linked to high axial length measurements.

Axial length

The baseline axial length measurement was taken from the closest biometry assessment before the date of surgery. The baseline axial length was categorised into 1-mm increments for graphical purposes (for example 20.00–20.99), where those <20 mm were grouped together as were those eyes ≥ 30 mm. Results for all recorded ocular co-pathologies are reported except for high myopia which is well known to be related to axial length and unspecified 'other' as the unspecified nature would hinder interpretation in the event of any observed associations with axial length.

Visual acuity

Preoperative visual acuity data was defined as the better value of uncorrected distance visual acuity (UDVA) or corrected distance visual acuity (CDVA).[10] Eligible VA measurements were recorded within 3 months prior to cataract surgery with the VA measurement closest to the date of cataract surgery used in the analysis.

Preoperative visual acuity values were recorded as Snellen or logMAR, and Snellen values were converted to logMAR for analyses. LogMAR values corresponding to count fingers (CF), hand movements (HM), perception of light (PL) and no perception of light (NPL) were substituted with 2.10, 2.40, 2.70 and 3.00 logMAR respectively. All analysis was conducted using STATA version 11 (StataCorp, College Station, TX, USA).

Posterior capsule rupture

'Posterior Capsular Rupture or vitreous loss or both' (abbreviated as PCR) was as previously defined,[10] namely as unintentional communication with the posterior segment from the occurrence of any of the following intraoperative complications: PCR with or without vitreous loss, zonule rupture with vitreous loss, vitreous

loss, vitreous to the section at the end of surgery, IOL into the vitreous or nuclear/ epinuclear fragment into the vitreous or the performing of any of an automated anterior vitrectomy, 'sponge and scissors vitrectomy,' secondary IOL or scleral fixed IOL during surgery; or if either of vitreous to the section or anterior chamber were recorded within 2 months of cataract surgery, or an operation for a dropped nucleus was recorded within 3 months of cataract surgery.

Results

Patient and eye demographics

Within the study period 180 114 cataract operations were performed for planned cataract surgery on patients aged 18 years or older using phacoemulsification. Excluded from the analysis were 61 operations, 58 as there was no baseline axial length measurements and 3 as the baseline axial length measurement was <15 mm. Eligible for analysis were 180 053 cataract operations performed on 88 467 (49.1%) left eyes and 91 586 (50.9%) right eyes from 127 653 patients by 994 surgeons, 66 of whom performed surgery at more than one grade.

Of the 127 653 patients, 51 820 (40.6%) were male, 75 451 (59.1%) female and the gender was not specified for 382 (0.3%) patients. At the time of the first eye cataract surgery, the median age of the patients was 77.1 (range; 18.1–109.7 years).

The mean and SD baseline axial length measurements were 23.43 and 1.38 mm. The mean -2, -1, +1 and +2 SD measurements were 20.67, 22.05, 24.80 and 26.18 mm respectively. The baseline axial length was <20.00 mm for 306 (0.2%) eyes, <21.00 mm for 2880 (1.6%) eyes, <22.00 mm for 18 354 (10.2%) eyes and >28.00 mm for 1882 (1.0%) eyes.

During the study period 52 400 (41.0%) patients had cataract surgery to both eyes where the median time between the first and second operations was 0.3 years (range; 0–4.2 years) and the median (modulus) difference in axial length measurements between the eyes was 0.01 mm.

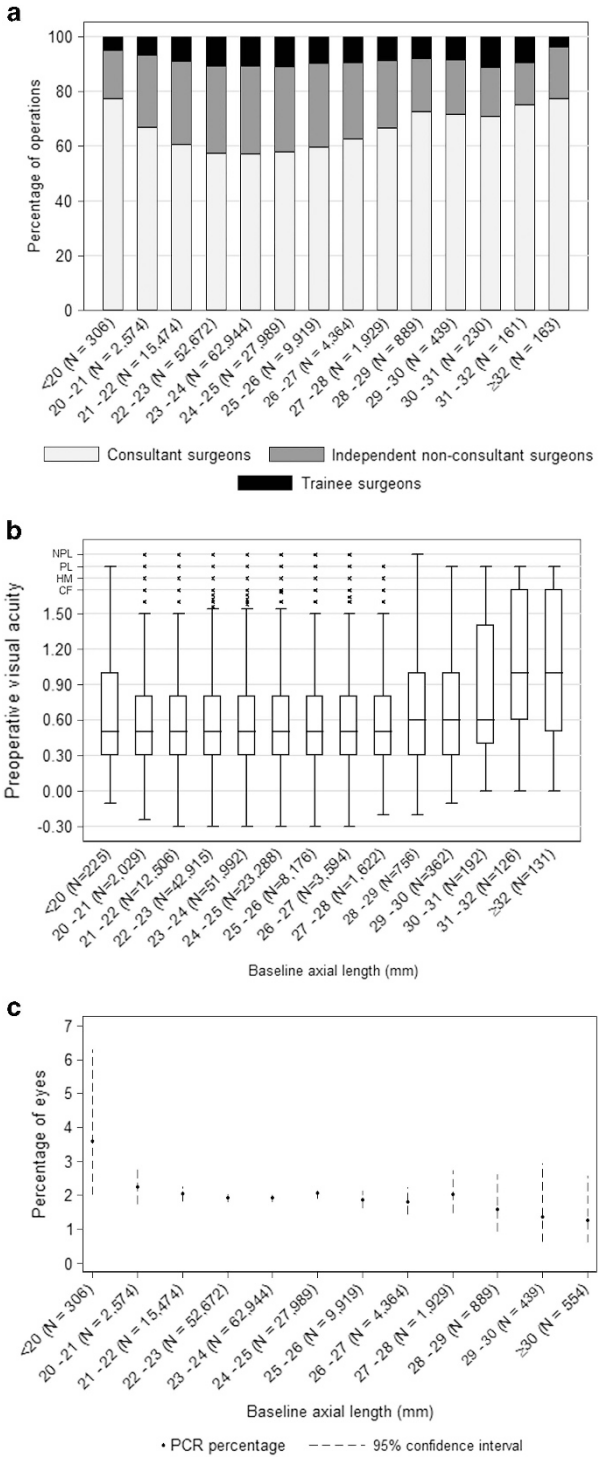

Figure 1 (a) The proportion of operations performed by each grade of surgeon according to baseline axial length. Consultant surgeons performed 105 078 operations, independent non-consultant surgeons 56 341 operations and trainee surgeons 18 634 operations. The axial length measurements were categorised into 1-mm increments except for measurements of <20 mm and ≥ 32 mm. (b) Box and whisker plots of preoperative visual acuity according to baseline axial length. The axial length measurements were categorised into 1 mm increments except for measurements of <20 mm and ≥ 32 mm. CF = Count fingers, HM, hand movements, PL, perception of light, NPL, no perception of light. The marks above the whiskers represent outlying values. (c) Posterior capsule rupture (PCR) rates with 95% confidence intervals by axial length (mm). The axial length measurements were categorised into 1 mm increments except for measurements of <20 mm and ≥ 30 mm.

Surgery

Two hundred and eighty four consultant surgeons performed 105 078 operations, 451 independent non-consultant surgeons performed 56 341 operations and 325 trainee surgeons performed 18 634 operations. Consultant surgeons performed a higher proportion of the operations on eyes at the extremities of the axial length scale, Figure 1a.

Preoperative visual acuity

Preoperative VA measurements were recorded for 147 914 (82.2%) eyes, of which 100 442 (67.9%) were CDVA measurements, 43 522 (29.4%) were UDVA measurements and for 3950 (2.7%) eyes the CDVA equalled the UDVA. The median and mean logMAR VA were 0.50 and 0.63 respectively, (Snellen approximations 6/19 and 6/25), including 6902 (4.7%) eyes with CF, 2969 (2.0%) eyes with HM, 818 (0.6%) eyes with PL and 50 (<0.1%) eyes with NPL. The presenting visual acuity varied over the axial length scale where the median VA was ~0.50 logMAR up to 28 mm and then at lower logMAR values afterwards, Figure 1b.

Ocular copathology

Ocular copathology (excluding high myopia and unspecified 'other') were present in 56 893 (31.6%) eyes. The most frequently recorded ocular co-pathologies were: AMD, glaucoma and diabetic retinopathy, which were recorded for 18 021 (10.0%), 14 407 (8.0%) and 8464 (4.7%) eyes, respectively. In general the presence of an ocular copathology was higher at the extremes of the axial length scale.

The proportion of eyes with AMD or diabetic retinopathy peaked between 22 and 23 mm and then decreased as the axial length increased, while the proportion of eyes with other macular pathology (1547 (0.9%) of eyes) was constant until 28 mm and increased with axial length thereafter, Figure 2a.

For both glaucoma and uveitis/synaechiae (1769 (1.0%) of eyes) the proportion of eyes with either of these co-pathologies was highest at the lower end of the axial length scale and rapidly decreased with increasing axial length measurements, Figure 2b.

Brunescent/white cataract and amblyopia were recorded for 5177 (2.9%) and 2678 (1.5%) eyes respectively and the proportions of eyes with either of these ocular copathologies were at the highest at the extremes of the axial length scale. Previous vitrectomy surgery was conducted on 2916 (1.6%) eyes and the proportion of eyes that had undergone vitrectomy surgery prior to cataract surgery increased as the axial length increased, Figure 2c.

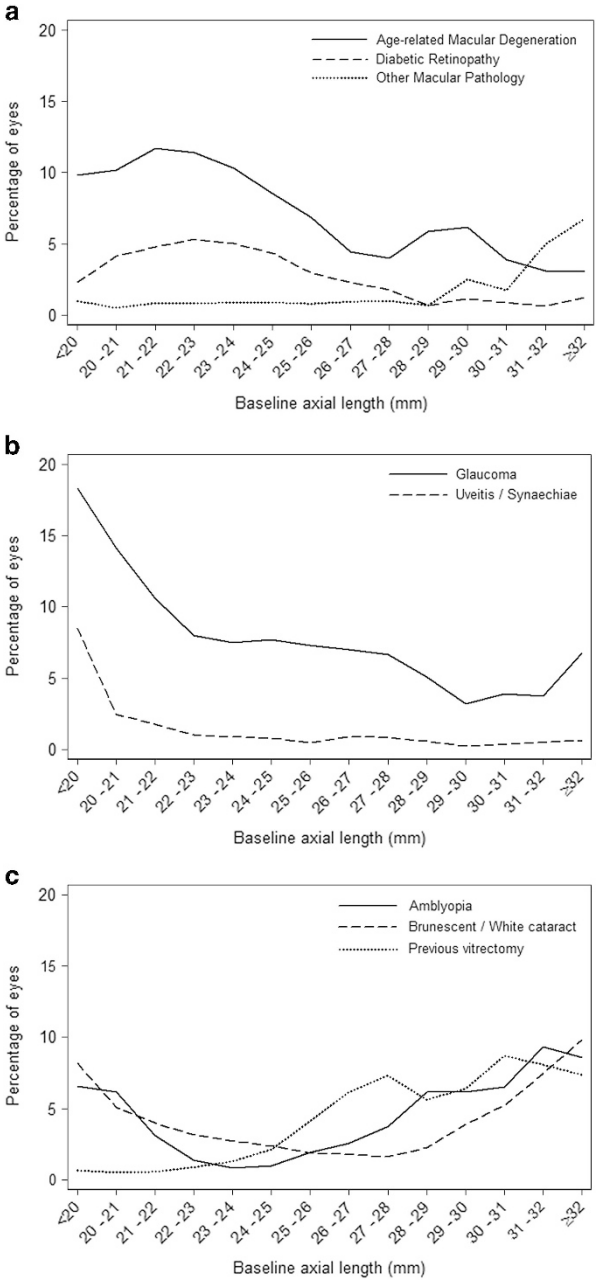

Figure 2 (a) The proportion of eyes with either of age-related macular degeneration, diabetic retinopathy or other macular pathology according to baseline axial length. (b) The proportion of eyes with either of glaucoma or uveitis/synaechiae according to baseline axial length. (c) The proportion of eyes with either of amblyopia, brunescent/white cataract or previous vitrectomy surgery according to baseline axial length. For all, the axial length measurements were categorised into 1 mm increments except for measurements of <20 mm and ≥32 mm.

Corneal pathology, pseudoexfoliation/phacodonesis, other retinal vascular pathology, no fundal view/vitreous opacities, optic nerve/CNS disease, and inherited eye diseases were recorded for 4246 (2.4%), 2227 (1.2%),

1520 (0.8%), 1358 (0.8%), 705 (0.4%), and 226 (0.1%) eyes respectively, and the proportion of eyes were similar across the axial length scale for all of these ocular co-pathologies.

Posterior capsule rupture or vitreous prolapse of both (PCR)

The overall the PCR rate was 1.95% (95% CI: 1.89 to 2.01%) with a borderline increase in those with an axial length of <20.0 mm (3.6%, 95% CI: 2.0 to 6.3%) compared to those with an axial length of ≥ 20.0 mm (1.95%, 95% CI: 1.89 to 2.01%), with an unadjusted odds ratio for this comparison of 1.88 (95% CI: 1.03 to 3.43, $P=0.0373$). PCR rates by axial length are shown in Figure 1c. The presence of brunescent/white cataract had an influence on the PCR rate at the extremity of the axial length scale, where the proportion of eyes with PCR and brunescent /white cataract accounted for 9.1, 22.4, 50.0 and 25.0% of the PCR rate for eyes with an axial length measurement of <20.0, 20.0–20.99, 31.0–31.99 and ≥ 32.0 mm, respectively.

Discussion

We found trends between axial length and ocular co-pathologies, pre-operative visual acuities and posterior capsule rupture rates.

Glaucoma and age related macular degeneration were more common in eyes with shorter axial lengths. At higher extremes of axial length (>31.0 mm), a trend towards higher rates of other macular pathology were observed. Our ocular copathology definitions were clinician defined and thus, for example, for glaucoma, cases will include both primary open angle and primary angle closure glaucoma in addition to secondary glaucomas. The association of shorter axial lengths with primary angle closure glaucoma has long been reported.[11] There is little data from large case series or population studies describing the trends of various ocular co-pathologies with axial length, however glaucoma has been associated with increasing axial length.[12] High axial length is considered an endophenotype for myopia and in the Blue Mountains Eye Study, POAG was 2.3 and 3.3 times more likely in eyes with low myopia and moderate to high myopia, respectively after adjusting for age, sex and other known glaucoma risk factors.[13] In the Beaver Dam Eye Study, myopia of more than -1.0D was associated with POAG (OR 1.6) after adjusting for age and sex.[14] Hyperopia of more than +1.0D was associated with ocular hypertension (OR 1.4).[14] In the Singapore Malay Eye Study (SiMES), an association was found for both moderate or high myopia (-4.0D or more, OR 2.8) and longer axial length (OR 3.0) with POAG after adjusting for various factors including central corneal thickness and intraocular pressure.[12] Further models investigating predictors of POAG found the association of POAG with moderate or high myopia to be no longer significant when also adjusting for axial length ($P<0.001$), thus suggesting globe axial length to be the main biometric risk factor for POAG.[12]

We found AMD was more common in eyes with lower axial lengths, and hyperopia has been associated with AMD in a number of case–control studies.[15–17] In, for example, the Age-Related Eye Disease Study (AREDS) persons with hyperopia were 1.3 times and 2.3 times more likely to have large drusen or neovascular AMD.[16] In population-based studies, findings have been less consistent. In the Rotterdam study, an association between hyperopia and AMD was found,[18] but in the Beaver Dam study there was no association between hyperopic refraction and the 10-year cumulative incidence of AMD after adjusting for age.[19] The axial length determinant of refraction is thought to be the most likely underlying factor for the association between hyperopia and AMD.[18] In the recent SiMES study, which was the first population-based study to investigate axial length and AMD; hyperopic refractive error and shorter axial length were associated with AMD after adjusting for age, sex, smoking, education, height, and blood pressure.[20] Each millimetre decrease in axial length was associated with a 29% increased risk of early AMD.[20] In an analysis of the Norwegian subgroup of the EUREYE community study of AMD, there was no association found between refraction or axial length and AMD.[21] The higher rates of 'other macular pathology' (Figure 2a) are likely accounted for by myopic macular degeneration including choroidal neovascularisation, although as already mentioned, ocular co-pathology definitions were clinician categorised at the time of surgery and thus no subanalysis is possible.

PCR rates were lower than expected for both very short and very long axial lengths. For eyes with axial length <20.0 mm the PCR rate in our series was 3.6% (95% CI: 2.0 to 6.3%). This was lower than expected with PCR rates of 11.7 and 12.5% previously reported for eyes with axial length <20.5 mm[22] and <20.0 mm[23] respectively. In this analysis, PCR rates for eyes with axial lengths >26.0, >27.0 and >30.0 mm were 1.8% (95% CI: 1.5 to 2.1%), 1.7% (95% CI: 1.4 to 2.2%) and 1.3% (95% CI: 0.6 to 2.5%), respectively. Previously reported PCR rates for eyes with axial lengths >26.0 and >27.0 mm range from 1.4 to 7.6%[24–27] and 6.0 to 9.3%[28,29] respectively. In a series by Zuberbuhler *et al* of eyes with axial length >30.0 mm, 6/177 (3.4%) had PCR using a definition similar to ours.[30] Certainly, as seen in Figure 1c, there is no apparent increase in PCR rates as axial length increases above 26.0 mm as would be expected based on previous studies, however

consultant surgeons did perform more cases at the extremes of axial length and in the first NOD cataract analysis we found intraoperative complication rates to be lower for consultant surgeons than other surgeon grades.[10]

Interestingly, increasing axial length has also been associated with more advanced levels of nuclear cataract and lower age at time of cataract surgery,[31] however we found no association between axial length and age at cataract surgery in this series. Eyes with brunescent/ white cataract were more common at both axial length extremes, suggesting that surgeons were presumably more reluctant to operate on these cases until there was more advanced cataract, perhaps due to expected poorer visual outcomes as a result of higher ocular co-pathology rates or anticipated higher PCR rates in eyes at axial length extremes. We found that eyes with brunescent/ white cataract and PCR accounted for 9% of the PCR rate for eyes with axial length of <20.0 mm compared to 22–50% for those 20.0 mm or longer. This suggests the higher PCR rate in eyes with axial length <20.0 mm is unlikely to be accounted for by the higher rates of brunescent/ white cataract in this group, although these results are from small samples and should be interpreted accordingly.

The main strength of this study is that the data were nonselective, pooled, and anonymized, so they may be more generalisable than data obtained from controlled trials, and less subject to publication bias than single-centre case series.[32] Clinicians were required to select the absence or presence of ocular co-pathologies from a specified list. The advantage of this is they are representative of those seen in daily clinical practice however there is the possibility of some degree of under-reporting, although this is unlikely to be biased with respect to axial length. A further limitation is that although the recording of intraoperative complications is mandatory on the EMR, its accuracy depends on surgeons recording their complications faithfully. It is not possible to confirm how reliably a surgeon records these, and surgeons may have a natural reluctance to record complications even though their results were anonymised.

Overall, this analysis reports pragmatic data from a national database of cataract surgery and gives an overview of the results and associations that may be anticipated in the UK NHS. In particular, PCR rates in eyes with very short or long axial lengths were lower than expected and rates of ocular comorbidities appear to vary by axial length which may provide insight into underlying pathological mechanisms if these findings are confirmed in population-based studies.

Summary

What was known before

- Rates of ocular comorbidities vary by axial length

What this study adds

- In patients undergoing cataract surgery in the UK, glaucoma, and age-related macular degeneration were more common in eyes with shorter axial lengths.
- Eyes with brunescent or white cataracts or amblyopia were more common at both axial length extremes.
- Posterior capsule rupture rates showed little change with axial length (mean 1.95%), except for a borderline increase in eyes with axial length <20.0 mm where rates were 3.6%.

Conflict of interest

PHJD's employer received unrestricted funding from The Special Trustees of Moorfield's Eye Hospital to analyse these data. RLJ is the Medical Director of Medisoft Limited, which developed the electronic medical record from which data were extracted, for the first iteration of the National Ophthalmology Database. The remaining authors declare no conflict of interest.

Author contributions

AD, PHJD, JMS, RLJ designed the study; PHJD contributed to the conduct of the study; AD, PHJD, RLJ contributed in collection, management, analysis, and interpretation of the data; AD, PHJD prepared the manuscript; AD, PHJD, JMS, RLJ reviewed the manuscript; AD, PHJD, JMS, RLJ contributed in the approval of the manuscript.

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Medscape EDUCATION

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

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1. Which of the following ocular conditions was associated with a longer axial length among patients undergoing cataract surgery?

   A Previous vitrectomy
   B Glaucoma
   C Age-related macular degeneration
   D Optic nerve disease

2. What was the relationship between brunescent or white cataracts and axial length in the current study?

   A Brunescent or white cataracts were more common in eyes with a shorter axial length only
   B Brunescent or white cataracts were more common in eyes with a longer axial length only
   C Brunescent or white cataracts were more common at the longer and shorter extremes of axial length
   D There was no significant relationship between brunescent or white cataracts and axial length

3. Preoperative visual acuity appeared to be ***most*** negatively affected by which of the following findings for axial length in the current study?

   A Less than 20 mm
   B 20 to 22 mm
   C 23 to 28 mm
   D Greater than 28 mm

4. Which of the following statements ***best*** describes the relationship between axial length and posterior capsular rupture, vitreous loss, or both (PCR) in the current study?

   A The PCR rate was high overall, regardless of axial length
   B Very short axial length was associated with a higher risk for PCR
   C Very long axial length was associated with a higher risk for PCR
   D There was a steady increase in the risk for PCR with increasing axial length

Activity evaluation

1. The activity supported the learning objectives.

Strongly disagree				Strongly agree
1	2	3	4	5

2. The material was organized clearly for learning to occur.

Strongly disagree				Strongly agree
1	2	3	4	5

3. The content learned from this activity will impact my practice.

Strongly disagree				Strongly agree
1	2	3	4	5

4. The activity was presented objectively and free of commercial bias.

Strongly disagree				Strongly agree
1	2	3	4	5