National Institute for Health and Care Excellence

1

Draft v2.0

Cataracts in adults

Cataracts in adults: management

Clinical Guideline <…>

Methods, evidence and recommendations

24 October 2017

Draft for Consultation

Commissioned by the National Institute for Health and Care Excellence

© National Institute for Health and Care Excellence 2017. All rights reserved.

Contents

3

Summary

A cataract is defined as any opacity in the crystalline lens of the eye. It can affect one or both eyes. The changes to the transparency and refractive index of the lens result in various levels of visual impairment. This impairment is associated with decreased quality of life because it may restrict the person's ability to carry out daily activities and function independently, while increasing the risk of accidents and falls.

Cataracts most commonly affect adults as a result of biological ageing (age-related cataracts) and may be classified according to the area of the lens that is affected (nuclear sclerotic, cortical or posterior subcapsular cataracts). Cataracts can also occur in children, and may be classified according to the age of onset (congenital or infantile/juvenile cataracts). This guideline only covers cataracts in people who are 18 years or older. Cataracts may occur secondary to hereditary factors, trauma, inflammation, metabolic or nutritional disorders, and exposure to radiation. In addition, lifestyle factors such as tobacco smoking and high alcohol intake are associated with an increased risk of developing age-related cataracts. Most cataracts are progressive, although the decline in visual function may be variable and unpredictable. The natural history of cataracts depends on the type and severity of the cataract and the presence of comorbid ocular conditions. In severe, untreated cases, cataracts can lead to significant reduction in vision, which is reversible with cataract surgery, although some level of visual impairment may persist.

Cataract surgery has a high success rate in improving visual function, with low morbidity and mortality. It is the most common operation performed in the NHS, with an ever growing need as the population ages.

Cataract management usually involves a multidisciplinary team that includes ophthalmologists, optometrists, nurses and technicians. Diagnosis is usually based on self-reported symptoms and a series of tests performed by an optometrist, normally based in the community. Symptoms may include blurred vision, difficulty seeing at night, sensitivity to light or glare, seeing 'halos' around lights and double vision in a single eye. Diagnostic tests include a visual acuity test, and slit-lamp and retinal examinations.

In adults with early age-related cataracts, non-surgical management may include prescription of spectacles. Alternatively, adults with age-related cataracts may be referred for surgery by an optometrist or a GP. The clinical threshold used to access cataract surgery varies across NHS trusts in England. This has resulted in differences in access to cataract surgery, since commissioning policies vary in scope and content and are not necessarily consistent with research evidence or guidance provided by the Department of Health in 'Action on cataracts' and the Royal College of Ophthalmologists' 'Cataract surgery guidelines'.

Guidance on appropriate referral criteria for cataract surgery is needed to address patient need and to optimise the allocation of NHS resources. In addition, an understanding of the most clinically and cost-effective methods for undertaking cataract surgery, and recommendations to minimise complications and surgical errors such as wrong intraocular lens implants, are needed to further improve patient care.

1 Guideline committee membership and ICG technical team

1.1 Guideline committee

Mike Burdon (Guideline Chair)
Consultant Ophthalmic Surgeon, University Hospitals Birmingham NHS Foundation Trust

Keith Allman (co-opted expert member)
Consultant Anaesthetist, Royal Devon and Exeter NHS Foundation Trust

Kamal Bishai
General Practitioner, NHS West Essex CCG

Arthur Brill
Patient/carer member

Michael Glowala (co-opted expert member)
Theatre Manager, York Teaching Hospital NHS Foundation Trust

Kate Kotschy (Until July 2015)
Patient/carer member

Emily Lam (From July 2015)
Patient/carer member

Janet Marsden
Professor of Ophthalmology and Emergency Care, Faculty of Health, Psychology and Social Care, Manchester Metropolitan University

Yvonne Needham
Senior Fellow, School of Health and Social Work, University of Hull

Ruth O'Dea (co-opted expert member, from March 2016)
Home Manager, Bemerton Lodge

Geoff Roberson
Professional Advisor, Association of Optometrists

Paul Rosen
Consultant Ophthalmic Surgeon, Oxford Eye Hospital, Oxford University Hospitals

Gillian Rudduck
Consultant Optometrist, Wirral University Teaching Hospital NHS Foundation Trust

Mary Russell (co-opted expert member, from March 2016)
Independence and Mobility Team, Royal National College for the Blind (Recently retired)

Nick Wilson-Holt
Consultant Ophthalmologist, Royal Cornwall Hospitals NHS Trust

Jennifer Yip
Consultant in Public Health, Public Health England & Clinical Associate Professor in Public Health Ophthalmology, London School of Hygiene & Tropical Medicine

For a full list of guideline development group and service delivery group declarations of interest, see Appendix A.

1.2 Internal Clinical Guidelines Team

Daniel Davies (From March 2016 to June 2016)
Project Manager

Sue Ellerby
Consultant Clinical Adviser

Gareth Franklin
Medicines Adviser

Christopher Gibbons
Health Economist

Wesley Hubbard
Information Specialist

Holly Irwin (Until February 2016)
Project Manager

Aimely Lee (From September 2016 to February 2017)
Technical Analyst

Hugh McGuire (Until December 2015)
Technical Adviser

Vonda Murray (From February 2016 to March 2016)
Project Manager

Adam O'Keefe (From June 2016)
Project Manager

Joshua Pink (From February 2016)
Technical Adviser

Stephen Robinson (From April 2016)
Technical Analyst

Gabriel Rogers
Technical Adviser, Health Economics

Susan Spiers
Associate Director

Sharlene Ting (Until February 2016 and then February 2017 to March 2017)
Technical Analyst

Jeremy Wight (From December 2015 to April 2016)
Consultant Clinical Adviser

2 Strength of recommendation

Some recommendations can be made with more certainty than others. The Guideline committee makes a recommendation based on the trade-off between the benefits and harms of an intervention, taking into account the quality of the underpinning evidence. For some interventions, the Guideline committee is confident that, given the information it has looked at, most patients would choose the intervention. The wording used in the recommendations in this guideline denotes the certainty with which the recommendation is made (the strength of the recommendation).

For all recommendations, NICE expects that there is discussion with the patient about the risks and benefits of the interventions, and their values and preferences. This discussion aims to help them to reach a fully informed decision (see also 'Patient-centred care').

Interventions that must (or must not) be used

We usually use 'must' or 'must not' only if there is a legal duty to apply the recommendation. Occasionally we use 'must' (or 'must not') if the consequences of not following the recommendation could be extremely serious or potentially life threatening.

Interventions that should (or should not) be used – a 'strong' recommendation

We use 'offer' (and similar words such as 'refer' or 'advise') when we are confident that, for the vast majority of patients, an intervention will do more good than harm, and be cost effective. We use similar forms of words (for example, 'Do not offer…') when we are confident that an intervention will not be of benefit for most patients.

Interventions that could be used

We use 'consider' when we are confident that an intervention will do more good than harm for most patients, and be cost effective, but other options may be similarly cost effective. The choice of intervention, and whether or not to have the intervention at all, is more likely to depend on the patient's values and preferences than for a strong recommendation, and so the healthcare professional should spend more time considering and discussing the options with the patient.

3 Methods

This guideline was developed in accordance with the process set out in 'Developing NICE guidelines: the manual (2014)'. There is more information about how NICE clinical guidelines are developed on the NICE website. A booklet, 'How NICE clinical guidelines are developed: an overview for stakeholders, the public and the NHS' is available. In instances where the guidelines manual does not provide advice, additional methods are used as described below, organised by study type.

3.1 Evidence synthesis and meta-analyses

Where possible, meta-analyses were conducted to combine the results of studies for each outcome. For continuous outcomes, where change from baseline data were reported in the trials and were accompanied by a measure of spread (for example standard deviation), these were extracted and used in the meta-analysis. Where measures of spread for change from baseline values were not reported, the corresponding values at study end were used and were combined with change from baseline values to produce summary estimates of effect. These studies were assessed to ensure that baseline values were balanced across the treatment groups; if there were significant differences at baseline these studies were not included in any meta-analysis and were reported separately.

3.2 Evidence of effectiveness of interventions

3.2.1 Quality assessment

GRADE was used to assess the quality of evidence for the selected outcomes as specified in 'The guidelines manual (2014)'. Where RCTs are available, these are initially rated as high quality and the quality of the evidence for each outcome was downgraded or not from this initial point. If non-RCT evidence was included for intervention-type systematic reviews then these are initially rated as low quality and the quality of the evidence for each outcome was downgraded or not from this point.

3.2.2 Methods for combining intervention evidence

Meta-analysis of interventional data was conducted with reference to the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al. 2011).

Dichotomous outcomes were pooled on the relative risk scale (using the Mantel–Haenszel method).

Random-effects models (der Simonian and Laird) were fitted for all syntheses, as a conservative approach that reflected the underlying clinical heterogeneity of interventions (for example, differences in surgical technique and lens choice even in otherwise similar studies), regardless of whether such heterogeneity could be statistically identified.

Meta-analyses were performed in Cochrane Review Manager v5.3.

3.2.3 Minimal clinically important differences (MIDs)

The Core Outcome Measures in Effectiveness Trials (COMET) database was searched to identify published minimal clinically important difference thresholds relevant to this guideline, which were considered along with any other published MIDs found during the clinical searches for the guideline, or any MIDs specified by the committee, and derived from their clinical experience. For relative risks, the GRADE default MID interval for dichotomous outcomes of 0.8 to 1.25 was used.

Cataract surgery has benefits across a wide variety of different domains of vision, with different people potentially benefiting in different ways. Examples would be improvements in visual acuity, depth of focus or contrast sensitivity, or reductions in the severity of optical abnormalities such as glare or halos. A person may gain a measurable benefit in one or some of these domains, without accruing any meaningful benefits in others. On this basis, the committee agreed that it would not be appropriate to specific quantitative MIDs for these intermediate outcome measures, as applying a population level MID to a dataset where only a proportion of people would be expected to benefit in that domain is likely to have the effect of inappropriately viewing differences as not being meaningful, where they may be for the proportion of people who do benefit.

The committee agreed, therefore, that wherever possible the focus would primarily be on measures such as visual function, quality of life or patient satisfaction, which should hopefully capture a more representative picture of the overall change. When decisions were made in situations where MIDs were not available, the 'Evidence to Recommendations' section of that review will make explicit the committee's view of the expected clinical relevance of the findings.

3.2.4 GRADE for pairwise meta-analyses of interventional evidence

The quality of the evidence for each outcome was downgraded where appropriate for the reasons outlined in Table 1

Table 1: Rationale for downgrading evidence for intervention studies

GRADE criteria	Reasons for downgrading quality
Risk of bias	The quality of the evidence was downgraded if there were concerns about the design or execution of the study, including concealment of allocation, masking, loss to follow up using intervention checklists in the NICE guidelines manual (2014)
Inconsistency	The quality of the evidence was downgraded if, after appropriate pre-specified sensitivity analyses were conducted, there were remaining concerns about inconsistency of effects across studies: occurring when there is variability in the treatment effect demonstrated across studies (heterogeneity). This was downgraded either if important differences were found between populations, interventions and/or comparators across studies include in a meta-analysis, or if there was significant unexplained statistical heterogeneity, assessed using the I^2 statistic, where $I^2 \geq 75\%$ was categorised as serious inconsistency.
Indirectness	The quality of the evidence was downgraded if there were concerns about the population, intervention and outcome in the included studies and how directly these variables could address the specific review question.
Imprecision	If MIDs (1 corresponding to meaningful benefit; 1 corresponding to meaningful harm) were defined for the outcome, the outcome was downgraded once if the 95% confidence interval for the effect size crossed 1 MID, and twice if it crossed both the upper and lower MIDs. If an MID was not defined for the outcome, it was downgraded once if the 95% confidence interval for the effect size crossed the line of no effect (i.e. the outcome was not statistically significant).

3.3 Methods for combining direct and indirect evidence (network meta-analysis) for interventions

Conventional pairwise meta-analysis involves the statistical combination of direct evidence about pairs of interventions that originate from 2 or more separate studies (for example, where there are two or more studies comparing A vs B).

In situations where there are more than 2 interventions, pairwise meta-analysis of the direct evidence alone is of limited use. This is because multiple pairwise comparisons need to be performed to analyse each pair of interventions in the evidence, and these results can be difficult to interpret. Furthermore, direct evidence about interventions of interest may not be available. For example studies may compare A vs B and B vs C, but there may be no direct evidence comparing A vs C. Network meta-analysis (NMA) overcomes these problems by combining all evidence into a single, internally consistent model, synthesising data from direct and indirect comparisons, and providing estimates of relative effectiveness for all comparators and the ranking of different interventions.

3.3.1 Synthesis

Two separate frameworks and software packages were used for undertaking network-meta analyses in this guideline, with the chosen method dependent on the specifics of the question (for certain datasets, it may be possible to run the preferred analysis in one program but not the other, or it may be particularly more efficient to use one package over another):

- Hierarchical Bayesian Network Meta-Analysis (NMA) was performed using WinBUGS version 1.4.3. The models used reflected the recommendations of the NICE Decision Support Unit's Technical Support Documents (TSDs) on evidence synthesis, particularly TSD 2 ('A generalised linear modelling framework for pairwise and network meta-analysis of randomised controlled trials'; see http://www.nicedsu.org.uk). The WinBUGS code provided in the appendices of TSD 2 was used without substantive alteration to specify synthesis models.

  Results were reported summarising 10,000 samples from the posterior distribution of each model, having first run and discarded 50,000 'burn-in' iterations. Three separate chains with different initial values were used.

  Non-informative prior distributions were used in all models. Unless otherwise specified, trial-specific baselines and treatment effects were assigned N(0,1000) priors, and the between-trial standard deviations used in random-effects models were given U(0,5) priors. These are consistent with the recommendations in TSD 2 for dichotomous outcomes.

  Fixed- and random-effects models were explored for each outcome, with the final choice of model based on deviance information criterion (DIC): if DIC was at least 3 points lower for the random-effects model, it was preferred; otherwise, the fixed effects model was considered to provide an equivalent fit to the data in a more parsimonious analysis, and was preferred.

  The network-meta analyses in sections 7.2 (biometry formulas) and 7.3 (biometry lens constants) were conducted using this methodology.

- Frequentist NMAs were undertaken using the `netmeta` package in R v3.3.1. This uses a graph-theoretical method which is mathematically equivalent to frequentist network meta-analysis (Rücker 2012). Inconsistency was assessed using the overall I^2 value for the whole network, which is a weighted average of the I^2 value for all comparisons where there are multiple trials (both direct and indirect), and random-effects models were used if the I^2 value was above 50% (this was interpreted as showing the assumption of consistent, shared underlying means was not met, and therefore a fixed-effects model was inappropriate).

  The network-meta analyses in sections 8.1 (lens design), 8.3 (multifocal vs monofocal intraocular lenses), 11.1 (anaesthesia) and 12.6 (preventing cystoid macular oedema) were conducted using this methodology.

Because different approaches and software had been applied, sensitivity analysis have previously been undertaken to establish whether this might have led to any substantive differences in output. Specimen dichotomous and continuous NMAs from the Bayesian analysis were rerun in the frequentist framework and generated results that were materially indistinguishable from the Bayesian version.

3.3.2 Applying GRADE to network meta-analysis

A modified version of the standard GRADE approach for pairwise interventions was used to assess the quality of evidence across the network meta-analyses undertaken. While most criteria for pairwise meta-analyses still apply, it is important to adapt some of the criteria to take into consideration additional factors, such as how each 'link' or pairwise comparison within the network applies to the others. As a result, the following was used when modifying the GRADE framework to a network meta-analysis. It is designed to provide a single overall quality rating for an NMA, which can then be combined with pairwise quality ratings for individual comparisons (if appropriate), to judge the overall strength of evidence for each comparison.

3.3.2.1 Risk of bias

In addition to the usual criteria to assess the risk of bias or 'limitations' of studies for each pairwise analysis within a network, the risk of bias was assessed for each direct comparison and assessed to see how it would affect the indirect comparisons. In addition, there was an assessment of treatment effect modifiers to see if they differed between links in the network.

For network meta-analyses with a large proportion of studies that were judged to be susceptible to bias, some downgrading decision rules were applied:

- If 50% or more studies in the network were inadequate or unclear for a particular parameter of quality, the outcome was downgraded by 1 level.
- As with pairwise meta-analyses, studies with differences in concomitant treatment between groups, or which did not report concomitant treatment between groups (where permitted), were treated with caution. Additionally, if there were differences in concomitant treatment among the studies included in different links across the network, the overall outcome was downgraded.

3.3.2.2 Inconsistency

Inconsistency was assessed for the heterogeneity of individual pairwise comparisons in the network, and also between direct and indirect comparisons where both were available (that is, where there were ‘loops’ in the network).

Heterogeneity across studies for each direct pairwise meta-analysis was assessed using I^2. This allowed for the assessment of heterogeneity within the included studies using the following decision rules:

- If there was considerable heterogeneity for 1 link or more in a network, the outcome was downgraded 1 level.
- If there was more than 1 link in the network with considerable, substantial or moderate heterogeneity, consideration was given to downgrading 2 levels.

To assess for consistency in each pairwise comparison where both direct and indirect evidence are available, the values of the direct and indirect estimates were compared to see if they were similar.

The overall values of I^2 (which combines heterogeneity between multiple studies of the same comparison and inconsistency between direct and indirect comparisons) and tau were also assessed to compare heterogeneity across the network.

3.3.2.3 Indirectness

As with pairwise meta-analyses, studies included in a network were assessed for how well they fit the PICO (population, intervention, comparator, outcome) specified in the review protocol.

3.3.2.4 Imprecision

Imprecision was assessed for a number of variables:

- Sufficient head-to-head trials in the network.
- Sufficient number of studies to form the network (if there was a high proportion of 'links' formed with only 1 trial, the outcome was downgraded).
- Overall certainty/uncertainty of the effect estimates (size of confidence/credible intervals, including for each drug compared with the reference option, and size of confidence/credible intervals for the overall rankings within the network).
- For networks, imprecision was considered around both the direct and indirect effect estimates.

3.4 Association studies

In this guideline, association studies are defined as those reporting data showing an association of a predictor (either a single variable or a group of variables) and an outcome variable, where the data are not reported in terms of outcome classification (i.e. diagnostic/prognostic accuracy). Data were reported as hazard ratios (if measured over time) or odds ratios (if measured at a specific time-point.

3.4.1 Methods for combining association study evidence

Hazard ratios were pooled using the inverse-variance method, and odds ratios were pooled using the Mantel-Haenszel method. Adjusted odds ratios from multivariate models were only pooled if the same set of predictor variables were used across multiple studies.

Random-effects models (der Simonian and Laird) were fitted for all syntheses, as a conservative approach that reflected the underlying clinical heterogeneity of interventions (for example, differences in surgical technique and lens choice even in otherwise similar studies), regardless of whether such heterogeneity could be statistically identified.

Meta-analyses were performed in Cochrane Review Manager v5.3.

3.4.2 Minimal clinically important differences (MIDs)

For odds ratios and adjusted odds ratios, an MID interval of 0.8 to 1.25 was used. No MID was specified for data reported as hazard ratios, and therefore the line of no effect was used.

3.4.3 Modified GRADE for association studies

GRADE has not been developed for use with predictive studies; therefore a modified approach was applied using the GRADE framework. Data from cohort studies was initially rated as high quality, and data from case-control studies as low quality, with the quality of the evidence for each outcome then downgraded or not from this initial point.

Table 2: Rationale for downgrading evidence for association studies

GRADE criteria	Reasons for downgrading quality
Risk of bias	Concerns about the design or execution of the study, including in how either the predictor or outcome variables were assessed, or loss to follow up during the study. These were identified using checklists in the NICE guidelines manual (2014).
Inconsistency	The quality of the evidence was downgraded if there were concerns about inconsistency of effects across studies: occurring when there is variability in the treatment effect demonstrated across studies (heterogeneity). This was

GRADE criteria	Reasons for downgrading quality
	assessed using the statistic, I^2 where ; $I^2 < 50\%$ was categorised as no inconsistency, and $I^2 \geq 50\%$ was categorised as serious inconsistency
Indirectness	Concerns about the population, intervention and outcome in the included studies and how directly these variables could address the specific review question.
Imprecision	If MIDs (1 corresponding to a meaningful increase; 1 corresponding to a meaningful decrease) were defined for the outcome, the outcome was downgraded once if the 95% confidence interval for the effect size crossed 1 MID, and twice if it crosses both the upper and lower MIDs. If an MID was not defined for the outcome, it was downgraded once if the 95% confidence interval for the effect size crossed the line of no effect (i.e. the outcome was not statistically significant).

3.5 Non-comparative studies

Throughout the guideline, wherever possible, data were always presented from comparative studies, with non-comparative studies only considered when this was the only data available. All non-comparative study designs (case series, audit data, surveys etc.) were analysed under the same framework, regardless of the underlying question they sought to address.

3.5.1 Modified GRADE for non-comparative evidence

GRADE has not been developed for use with non-comparative studies; therefore a modified approach was applied using the GRADE framework, with the approach summarised in Table 3.

Table 3: Rationale for downgrading evidence for non-comparative evidence

GRADE criteria	Reasons for downgrading quality
Risk of bias	Concerns about the design or execution of the study, including participant recruitment, retention and outcome measurement
Inconsistency	Data from non-comparative studies were not pooled together at any stage, and therefore it was not possible to assess inconsistency.
Indirectness	Concerns about the population, intervention and outcome in the included studies and how directly these variables could address the specific review question.
Imprecision	If the upper and lower limits of the 95% confidence interval were such that, if they represented the true result, they would imply qualitatively different conclusions (e.g. it is possible that either a moderate or small proportion of people experience a given event), the outcome was downgraded one level. If the mean estimate, the upper limit, and the lower limit of the 95% confidence interval, were such that, if they represented the true result, they would all imply qualitatively different conclusions (e.g. it is possible that either a small, moderate or small proportion of people experience a given event), the outcome was downgraded two levels.

3.6 Qualitative evidence

3.6.1 Methods for combining qualitative evidence

Where multiple qualitative studies were identified for a single question, information from the studies was combined using a thematic synthesis. By examining the findings of each included study, descriptive themes were independently identified and coded. Once all of the included studies had been examined and coded, the resulting themes and sub-themes were evaluated to examine their relevance to the review question, the importance given to each

theme, and the extent to which each theme recurred across the different studies. The qualitative synthesis then proceeded by using these 'descriptive themes' to develop 'analytical themes', which were interpreted by the reviewer in light of the overarching review questions.

3.6.2 CERQual for qualitative studies

CERQual was used to assess the confidence we have in each of the identified themes. Evidence from all qualitative study designs (interviews, focus groups etc.) was initially rated as high confidence and the confidence in the evidence for each theme was then downgraded from this initial point as detailed in Table 4 below.

Table 4: Rationale for downgrading evidence for qualitative questions

CERQual criteria	Reasons for downgrading confidence
Methodological limitations	The extent to which there are problems in the design or conduct of the primary studies that contributed evidence to a review finding. Where the primary studies underlying a review finding are shown to have important methodological limitations, we are less confident that the review finding reflects the phenomenon of interest.
Relevance	Relevance is the extent to which the body of evidence from the primary studies supporting a review finding is applicable to the context specified in the review question. This may relate to, for example, the perspective or population researched, the phenomenon of interest or the setting. Where the contexts of the primary studies underlying a review finding are substantively different to the context of the review question, we are less confident that the review finding reflects the phenomenon of interest.
Coherence	Coherence was addressed based on two factors: • Between study – does the theme consistently emerge from all relevant studies • Theoretical – does the theme provide a convincing theoretical explanation for the patterns found in the data The outcome was downgraded once if there were concerns about one of these elements of coherence, and twice if there were concerns about both elements.
Adequacy of data	The outcome was downgraded if there was insufficient data to develop an understanding of the phenomenon of interest, either due to insufficient studies, participants or observations.

3.7 Mixed-quantitative and qualitative evidence

Where a review question identified both relevant quantitative and qualitative evidence, these two types of evidence were analysed separately, using the relevant GRADE, modified GRADE or CERQual criteria defined above.

3.8 Health economics

Literature reviews seeking to identify published cost–utility analyses of relevance to the issues under consideration were conducted for all questions. In each case, the search undertaken for the clinical review was modified, retaining population and intervention descriptors, but removing any study-design filter and adding a filter designed to identify relevant health economic analyses. Search strategies are provided in full in Appendix D. In assessing studies for inclusion, population, intervention and comparator, criteria were always identical to those used in the parallel clinical search; only cost–utility analyses were included. Economic evidence profiles, including critical appraisal according to the Guidelines manual, were completed for included studies; these are shown in Appendix J.

Economic studies identified through a systematic search of the literature are appraised using a methodology checklist designed for economic evaluations (NICE 2012; Appendix F). This checklist is not intended to judge the quality of a study per se, but to determine whether an existing economic evaluation is useful to inform the decision-making of the committee for a specific topic within the guideline.

There are 2 parts of the appraisal process. The first step is to assess applicability (that is, the relevance of the study to the specific guideline topic and the NICE reference case); evaluations are categorised according to the criteria in Table 5.

Table 5 Applicability criteria

Level	Explanation
Directly applicable	The study meets all applicability criteria, or fails to meet one or more applicability criteria but this is unlikely to change the conclusions about cost effectiveness
Partially applicable	The study fails to meet one or more applicability criteria, and this could change the conclusions about cost effectiveness
Not applicable	The study fails to meet one or more applicability criteria, and this is likely to change the conclusions about cost effectiveness. These studies are excluded from further consideration

In the second step, only those studies deemed directly or partially applicable are further assessed for limitations (that is, methodological quality); see categorisation criteria in Table 6.

Table 6 Methodological criteria

Level	Explanation
Minor limitations	Meets all quality criteria, or fails to meet one or more quality criteria but this is unlikely to change the conclusions about cost effectiveness
Potentially serious limitations	Fails to meet one or more quality criteria and this could change the conclusions about cost effectiveness
Very serious limitations	Fails to meet one or more quality criteria and this is highly likely to change the conclusions about cost effectiveness. Such studies should usually be excluded from further consideration

Where relevant, a summary of the main findings from the systematic search, review and appraisal of economic evidence is presented in an economic evidence profile alongside the clinical evidence.

Original health economic modelling was available to support the Guideline Committee's decision making for the cataract surgery questions addressed in sections 6.1 and 10.2. The Committee prioritised areas in which they felt that original analysis would be particularly informative, on the grounds of uncertainty and variation in current practice and/or the presence of complex trade-offs between the benefits, harms and costs of various courses of action. In questions for which no published evidence was identified and original analysis was not prioritised, the committee made a qualitative judgement about cost effectiveness by considering potential differences in resource use and cost between the options alongside the results of the review of evidence of clinical effectiveness.

3.9 External collaborations

A number of questions in this guideline were undertaken as a collaboration between the NICE Internal Guidelines Team and the Cochrane Eyes and Vision Group. Data from

relevant Cochrane reviews were supplied to the NICE team, and then either the full or relevant subsection of the review included as part of the evidence base. The following questions were undertaken as collaborations:

- What is the optimal strategy to facilitate simultaneous distance and near vision following cataract surgery? (section 8.4)
- What is the effectiveness of laser-assisted phacoemulsification cataract surgery compared with standard ultrasound phacoemulsification cataract surgery? (section 10.1)
- What is the effectiveness of prophylactic antiseptics (for example, topical iodine) and antibiotics to prevent endophthalmitis after cataract surgery? (section 12.5)
- What is the effectiveness of prophylactic topical corticosteroids and/or NSAIDs to prevent inflammation and cystoid macular oedema after phacoemulsification cataract surgery? (section 12.6)

Details of the collaboration for each question are explained in the relevant chapters. Where Cochrane reviews have been incorporated without substantive modification, the evidence is presented as it was in the original Cochrane review. Where modifications have been made to the published reviews (e.g. to standardise methodology with the rest of the guideline), these are presented in the same format as the original reviews undertaken for this guideline, and deviations from the data presented in the Cochrane reviews clearly specified.

4 Summary of recommendations

4.1 Recommendations summary

1. Give people with cataracts, and their family members or carers (as appropriate), both oral and written information. Information should be tailored to the person's needs, for example, in an accessible format. For more guidance on giving information to people and discussing their preferences, see the NICE guideline on patient experience in adult NHS services, particularly recommendations 1.2.12 and 1.2.13 on capacity and consent.
2. At referral for cataract surgery (also see section 6.1), give people information about:
    - cataracts:
        - what cataracts are
        - how they can affect vision
        - how they can affect quality of life
    - cataract surgery:
        - what it involves and how long it takes
        - possible risks and benefits
        - what support might be needed after surgery
        - likely recovery time
        - how vision and quality of life may be affected without surgery.
3. At the preoperative outpatient appointment, review and expand on the topics in recommendation 2, and give people information about:
    - the refractive implications of different intraocular lenses (see recommendation 29)
    - types of anaesthesia
    - the person's individual risk of complications during or after surgery (for example, the risk of postoperative retinal detachment in people with high myopia; also see recommendations 17 and 18)
    - what to do and what to expect on the day of cataract surgery
    - what to do and what to expect after cataract surgery
    - what support might be needed after surgery
    - medicines after surgery (for example, eye drops) and medicines that people may be already taking (for example, anticoagulants).
    - the refractive implications after previous corneal refractive surgery, if appropriate (see recommendation 13)
    - bilateral simultaneous cataract surgery, if appropriate (also see recommendations 37 and 38)
4. On the day of surgery, before the operation, give people information about:
    - their position on the list

- what to expect during and after surgery.

5. On the day of surgery, after the operation, give people information about:
   - what visual changes to expect
   - signs and symptoms of potential complications to look out for
   - any restrictions on activities, for example, driving
   - possible problems and who to contact
   - emergency situations and who to contact
   - eye drops
   - pain management
   - their next appointment and who they will see.
6. Base the decision to refer a person with a cataract for surgery on a discussion with them (and their family members or carers, as appropriate) that includes:
   - how the cataract affects the person's vision and quality of life
   - whether 1 or both eyes are affected
   - what cataract surgery involves, including possible risks and benefits
   - how the person's quality of life may be affected if they choose not to have cataract surgery
   - whether the person wants to have cataract surgery.
7. Do not restrict access to cataract surgery on the basis of visual acuity.
8. Use optical biometry to measure the axial length of the eye for people having cataract surgery.
9. Use ultrasound biometry if optical biometry does not give accurate measurements.
10. Use keratometry to measure the curvature of the cornea for people having cataract surgery.
11. Consider corneal topography for people having cataract surgery:
    - who have abnormally flat or steep corneas
    - who have irregular corneas
    - who have significant astigmatism
    - who have had previous corneal refractive surgery **or**
    - if it is not possible to get an accurate keratometry measurement.
12. For people who have not had previous corneal refractive surgery, use one of the following to calculate the intraocular lens power before cataract surgery:
    - If the axial length is less than 22.00 mm, use Haigis or Hoffer Q.
    - If the axial length is between 22.00 and 26.00 mm, use Barrett Universal II if it is installed on the biometry device and does not need the results to be transcribed by hand. Use SRK/T if not.
    - If the axial length is more than 26.00 mm, use Haigis or SRK/T.
13. Advise people who have had previous corneal refractive surgery that refractive outcomes after cataract surgery are difficult to predict, and that

546 they may need further surgery if they do not want to wear spectacles for
547 distance vision.

548 14. If people have had previous corneal refractive surgery, adjust for the
549 altered relationship between the anterior and posterior corneal curvature.
550 Do not use standard biometry techniques or historical data alone.

551 15. Surgeons should think about modifying a manufacturer's recommended
552 intraocular lens constant, guided by learning gained from their previous
553 deviations from predicted refractive outcomes.

554 16. Consider using 50% of the first eye prediction error in observed refractive
555 outcome to guide calculations for the intraocular lens power for second-
556 eye cataract surgery.

557 17. Consider using a validated risk stratification algorithm for people who
558 have been referred for cataract surgery, to identify people at increased
559 risk of complications during and after surgery.

560 18. Explain the results of the risk stratification to the person, and discuss how
561 it may affect their decisions.

562 19. To minimise the risk of complications during and after surgery, ensure that
563 surgeons in training are closely supervised when they perform cataract
564 surgery in:

565 - people who are at high risk of complications **or**

566 - people for whom the impact of complications would be especially
567 severe (for example, people with only 1 functional eye).

568 20. Explain to people who are at risk of developing a dense cataract that there
569 is an increased risk of complications if surgery is delayed and the cataract
570 becomes more dense.

571 21. Offer square-edged hydrophobic acrylic or silicone intraocular lenses to
572 people having cataract surgery, to reduce the risk of posterior capsule
573 opacification.

574 22. Do not use blue-light filtering intraocular lenses in cataract surgery, unless
575 as part of a research study.

576 23. Do not offer multifocal intraocular lenses for people having cataract
577 surgery.

578 24. Offer monovision after cataract surgery to people who:

579 - are already using monovision **or**

580 - have had a successful contact lens trial before cataract surgery.

581 25. Consider on-axis surgery or limbal-relaxing incisions to reduce
582 postoperative astigmatism.

583 26. Before the preoperative biometry assessment, ensure that the person's
584 correct medical notes are used by confirming the person's:

585 - name

586 - address **and**

587 - date of birth.

588 27. Immediately after the preoperative biometry assessment:

589 - securely fix the printed biometry results to the person's medical
590 notes

- check that the results include the person's name, address, date of birth and hospital number
- use electronic data transfer if uploading the results to an electronic health record
- do not transcribe the results by hand.

28. At the preoperative assessment:
    - discuss the refractive implications of different intraocular lenses with the person
    - base the choice of intraocular lens on the person's chosen refractive outcome
    - record the discussion and the person's choices in their medical notes.
29. The person's medical notes, including printed biometry results, must be available in theatre on the day of the cataract surgery.
30. Use a checklist based on the World Health Organization (WHO) surgical safety checklist, modified to include the following cataract surgery checks, to ensure that:
    - the person's identity has been confirmed and matches information in:
        - the consent form
        - the printed biometry results **and**
        - the person's medical notes
    - the eye to be operated on has been checked and clearly marked
    - there is only 1 intraocular lens in the theatre, that matches the person's selected lens type and prescription
    - at least 1 additional identical intraocular lens is in stock
    - alternative intraocular lenses are in stock in case the selected lens needs to be changed if there are complications during surgery
    - at least 2 members of the team, including the surgeon, have checked the appropriateness, accuracy and consistency of all:
        - formulas
        - calculations **and**
        - intraocular lens constants.
31. Before giving the person anaesthetic, ensure that:
    - there is only 1 intraocular lens in the theatre, that matches the person's selected lens type and prescription
    - at least 1 additional identical intraocular lens is in stock
    - alternative intraocular lenses are in stock in case the selected lens needs to be changed if there are complications during surgery.
32. Immediately before the operation, the surgeon should:

- confirm the person's identity and ensure that the correct medical notes are being used, especially if using electronic patient records
- refer to the printed biometry results, not to transcribed information in the person's medical notes
- refer to the person's medical notes to check which refractive outcome they preferred
- verify that the correct intraocular lens has been selected and is available in theatre.

33. If a wrong lens is implanted, refer to NHS England's Never Events policy, and together with the whole multidisciplinary team:
    - undertake a root-cause analysis to determine the reasons for the incident
    - establish strategies and implementation tools to stop it from happening again.
34. Do not use femtosecond laser-assisted cataract surgery unless it is part of a randomised controlled trial comparing femtosecond laser-assisted cataract surgery with ultrasound phacoemulsification.
35. Offer second-eye cataract surgery using the same criteria as for the first eye surgery (see section 6 for referral for cataract surgery).
36. Consider bilateral simultaneous cataract surgery for people who are at low risk of complications during and after surgery.
37. Discuss the potential benefits and harms of bilateral simultaneous cataract surgery with people, which should include:
    - the potential immediate visual improvement in both eyes
    - how it will not be possible to choose a different intraocular lens based on the outcome in the first eye
    - the risk of complications in both eyes during and after surgery that could cause long-term visual impairment
    - the likely need for additional support after the operation.
38. Offer sub-Tenon's or topical (with or without intracameral) anaesthesia for people having cataract surgery.
39. If both sub-Tenon's and topical (with or without intracameral) anaesthesia are contraindicated, consider peribulbar anaesthesia.
40. Do not offer retrobulbar anaesthesia for people having cataract surgery.
41. Consider sedation, administered by an experienced ophthalmic anaesthetist, as an adjunct to anaesthesia for people if, for example:
    - they have high levels of anxiety
    - they have postural or musculoskeletal problems
    - surgery is expected to take longer than usual.
42. Consider hyaluronidase as an adjunct to sub-Tenon's anaesthesia, particularly if trying to stop the eye moving during surgery.
43. Consider intracameral phenylephrine to increase pupil size in people at risk of floppy iris syndrome.
44. When dealing with posterior capsule rupture, follow a protocol that covers:

- removing vitreous from the wound and anterior chamber
- minimising traction on the retina
- removing lens fragments in the posterior chamber or vitreous cavity
- removing soft lens matter
- implications for any lens insertion.

45. Do not use capsular tension rings in routine, uncomplicated cataract surgery.
46. Consider using capsular tension rings for people with pseudoexfoliation.
47. Use preoperative antiseptics in line with standard surgical practice.
48. Use intracameral cefuroxime during cataract surgery to prevent endophthalmitis.
49. Use commercially prepared or pharmacy-prepared intracameral antibiotic solutions to prevent dilution errors.
50. Consider topical steroids in combination with NSAIDs:
    - after cataract surgery for people at increased risk of cystoid macular oedema, for example, people with diabetes or uveitis
    - to manage cystoid macular oedema.
51. Offer topical steroids and/or non-steroidal anti-inflammatory drugs (NSAIDs) after cataract surgery to prevent inflammation and cystoid macular oedema.
52. Offer eye protection for people whose eye shows residual effects of anaesthesia at the time of discharge after cataract surgery.
53. Commissioners and service providers should ensure that the following are in place:
    - Processes that identify complications after surgery and ensure that there is prompt access to specialist ophthalmology services.
    - Processes to ensure that the postoperative section of the UK Minimum Cataract Dataset for National Audit is collected and has been entered into an electronic dataset.
    - Arrangements so that healthcare professionals discuss second-eye cataract surgery with people who have a cataract in their non-operated eye.
54. Consider collecting patient visual function and quality of life data for entry into an electronic dataset.
55. Do not offer in-person first-day review to people after uncomplicated cataract surgery.
56. At the first appointment after cataract surgery, give people information about:
    - eye drops
    - what to do if their vision changes
    - who to contact if they have concerns or queries
    - when it is appropriate to get new spectacles and how to do so
    - second-eye cataract surgery if there is a cataract in the non-operated eye

- arrangements for managing ocular comorbidities.

4.2 Research recommendations summary

1. What is the association between preoperative vision- and health-related quality of life on postoperative vision- and health-related quality of life, and self-reported postoperative improvement?
2. What vision-specific quality of life measures best capture visual changes in a population with cataracts?
3. What is the effectiveness and cost effectiveness of biometry techniques in adults undergoing phacoemulsification cataract surgery with a history of corneal refractive surgery?
4. How effective are newer intraocular lens formulas (for example, Barrett, Olsen, T2) compared with standard formulas for phacoemulsification cataract operations on eyes without a history of corneal refractive surgery, especially for long and short axial lengths?
5. What is the effectiveness of different intraocular lens formulas for eyes after prior corneal refractive surgery, as measured in a prospectively collected multi-centre study?
6. What are the long-term outcomes of different choices of intraocular lens material following cataract surgery?
7. What are the long-term rates of and reasons for lens explantation after cataract surgery?
8. What is the effect of differences in contrast sensitivity and depth of focus on overall visual function and quality of life?
9. What is the long-term effectiveness of blue light filtering IOLs in reducing the incidence and/or progression of age-related macular degeneration?
10. What is the effectiveness of different approaches to monovision (the degree of anisometropia) versus standard monofocal lenses?
11. What is the cost effectiveness of toric lenses compared with on-axis or limbal-relaxing incision surgery, or non-toric lenses with no further intervention, in an NHS context, taking account of the whole care pathway cost implications from pre- to postoperative phases, stratified by the preoperative level of astigmatism?
12. What is the effectiveness and cost effectiveness of limbal relaxing incisions (in combination with any intraocular lens type) to reduce postoperative astigmatism?
13. What is the long-term effectiveness of capsular tension rings in people with pseudoexfoliation undergoing cataract surgery?
14. What is the effectiveness of postoperative antibiotic drops to reduce rates of endophthalmitis after cataract surgery?
15. What is the most effective postoperative medical management for cystoid macular oedema?
16. What is the risk of postoperative retinal detachment in people with high myopia?

5 Patient information

Providing services that reflect the needs and preferences of patients, their families and their carers is one of the core principles that define NHS values, as outlined in the NHS Constitution. Patients, with their families and carers where appropriate, should be involved in and consulted on all decisions about their care and treatment. Whilst no-one could disagree with this code of practice, the practice itself can sometimes suffer from a lack of time, resources and accessible information.

A cataract operation can be a daunting experience for patients, most of whom are older, some with other medical conditions, which can create additional concerns for both clinician and patient. Clinicians should engage in collaborating with the patient in their care, ensuring they provide care that is patient centred, tailored and co-ordinated to the needs of the individual. Throughout the patient journey, from diagnosis, to the operation and after care, there should always be opportunities and time for questions and information.

Patient centred information is essential in supporting individuals to develop the knowledge and confidence they need to make informed decisions about their health and healthcare. This includes clear written information which outlines the individual steps of the operation as well as pre and postoperative care.

Adequate explanation of the risks and benefits for the individual patient, ideally including treatment options and expertise offered by the surgeon, will assist the patient / carer in their decision-making regarding surgery. Clear explanations can allay anxiety, increase understanding and in turn secure patient cooperation and compliance. This helps them prepare preoperatively, during the operation, and in organising after care arrangements, such as organising a family carer or someone to assist in returning home after the operation.

A realistic discussion between the surgical team and the patient preoperatively about likely postoperative outcomes including vision, quality of life (both visual and general, where they can be reasonably predicted), driving ability and probable timescale involved, whilst allowing opportunities for patient to ask questions, should go some way towards ensuring patients have realistic expectations, leading to greater satisfaction after surgery.

Most importantly of all, patients should always be treated with dignity, compassion and respect.

Though there is little evidence to support specific interventions to improve patient centred care in cataract surgery, common sense should prevail; surgeons, nurses and optometrists should commit to consultations which are a mutual process of information sharing and joint decision making in order to ensure the best clinical outcomes that are satisfactory for both parties.

5.1 Patient information

5.1.1 Review questions

- What information do people with cataracts and their carers find useful, and what format do they prefer it to be provided in?
- What information on cataract surgery do people and their carers find useful when deciding whether surgery is appropriate for them, and before, during and after any operation(s) they elect to undergo? What format do they prefer it to be provided in?

5.1.2 Introduction

In order to inform the content, utility and applicability of literature on cataracts and/or cataract surgery, the aim of this review was to determine the information needs of:

- People who are diagnosed with a cataract and their carers; and
- People considering, about to undergo, or who have recently undergone cataract surgery and their carers

The review focused on identifying studies that fulfilled the conditions specified in Table 7. For full details of the review protocols, see Appendix C.

Table 7: PICO inclusion criteria for information needs for people with cataracts and their carers

Population	Adults (18 years and over) diagnosed with non-trauma related cataracts or their carers
Information needs	Any information needs identified in the literature that are specific to people with cataracts and their carers
Factors of interest	Themes surrounding patients' or carers' educational or information needs such as: • information on prognosis • self-management • treatment options • self-management following surgery • risks of complications

Qualitative surveys or interviews were considered to be the most appropriate study designs to derive patient and carer information needs. Papers were excluded if they:

- were non-qualitative research, narrative reviews, commentaries, editorials/letters, opinion pieces or case studies/reports
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary population of people with different eye pathologies.
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

5.1.3 Evidence review

An overarching systematic search was conducted to inform the review questions on patient information (see Appendix D), which identified 4,314 references. Due to the low volume of relevant evidence obtained, the inclusion criteria for including studies from that search were broadened to also include studies where qualitative data had been collected, but then quantitatively analysed (e.g. studies reporting the proportion of people expressing a certain opinion). The references were screened on their titles and abstracts and full papers of 18

references were obtained and reviewed against the inclusion and exclusion criteria in the review protocols (see Appendix C).

Overall, 15 studies were excluded as they did not meet the eligibility criteria, for reasons such as not being a qualitative design or not reporting any outcomes of interest. Of the remaining 3 studies that did meet the eligibility criteria, 1 was a focus group study, 1 was a questionnaire study and 1 was a survey study.

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

5.1.3.1 Description of included studies

One prospective survey study (Tan et al., 2008) investigated 100 patients' preferences for information and discussion prior to routine cataract surgery. All patients had already been given standard information, including written information, at the time of listing for surgery. Age ranged between 22 to 99 years old (mean age 74.7 years), with 70% being in their 70s and 80s and 51% were male.

One study (Elder & Suter, 2004) administered a questionnaire to 190 patients before cataract surgery to clarify what preoperative information patients wanted before a patient can be said to have made an 'informed decision'. The average age was 75.49 years and 59.7% were female. Two-thirds of patients were to undergo their first cataract operation.

One study (Nijkamp et al., 2002) conducted 4 focus groups with 27 patients (5–8 patients per group) to identify factors that are related to fear among patients who need to undergo cataract surgery. Age ranged between 50 to 87 years (mean age 72.2 years) and 56% were women.

Full details of the included studies are found in the evidence tables (see Appendix E), with GRADE tables for quantitative data and CERQual tables for qualitative data given in Appendix G.

5.1.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which none were retained for this review question. Health economic modelling was not prioritised for this review question.

5.1.5 Evidence statements

5.1.5.1 Qualitative evidence

One focus group study exploring factors related to fear in 27 patients identified the following themes relating to information provision for people undergoing cataract surgery (moderate confidence evidence base):

- At home after diagnosis:
  - Importance of patient information and reassurance.
  - Importance of a positive doctor–patient relationship.
  - Importance of positive social support.
  - People undergoing second-eye surgery were more relaxed than those undergoing first-eye surgery.
- Preparation for surgery at hospital;
  - Fears could be reduced by providing comprehensive information about anaesthesia and the operation itself.

- People varied considerably in the amount of information they wanted before surgery.
- Oral information was preferred over written information.

- Day of surgery:
  - Trust was boosted by reassuring comments from the ophthalmologist during surgery.
  - People reported feeling fear or distress if they experienced unexpected sensations of pain or discomfort during surgery.
- Postoperative visits:
  - People were confused by unclear, incomplete or contradictory patient information, and felt that unambiguous guidance about postoperative restrictions would generate reassurance.
- Recovery at home:
  - If not properly informed, patients worried about deteriorations in visual acuity over the recovery period.

5.1.5.2 Quantitative evidence

Moderate-quality evidence from 1 survey of 100 participants found that, in addition to receiving standard information about cataract surgery at the time of listing for surgery, 32 did not wish to know "anything at all" about risks and would prefer to leave decision-making to their ophthalmologists; 22 were interested only in knowing their overall chance of visual improvement; and 46 welcomed a discussion of possible complications.

Moderate-quality evidence from 1 questionnaire study of 190 participants found that, before cataract surgery, the most important information was the chance of visual improvement after surgery, followed by when vision would improve; the overall risk of losing vision from the surgery; the consequences of not having the operation and the types of serious complications.

Moderate-quality evidence from 1 questionnaire of 190 participants found that the majority of people preferred that preoperative information be provided in both a verbal and written format.

5.1.5.3 Health Economic Evidence

No health economic evidence was identified for this review question.

5.1.6 Evidence to recommendations

Relative value of different outcomes	The committee stated that themes surrounding patients' or carers' educational or information needs before and after cataract surgery would all be relevant outcomes. They agreed that whilst qualitative data were the most relevant for addressing this question, quantitatively analysed data (such as the proportions of people who wanted to receive certain types of information) would also be of value.
Trade-off between benefits and harms	The committee agreed that the quantitative evidence presented clearly demonstrated that a large majority of people had a preference for being given both verbal and written information, and agreed it was appropriate to make an overarching recommendation to this effect across the whole patient information section. They also agreed it would be appropriate at this point to cross-refer to the general NICE guidance on patient experience, which gives guidance on making information accessible to patients and their carers.

	The committee agreed that both the quantitative and qualitative evidence presented showed a clear structure of different stages at which information was necessary. This began at the time of initial diagnosis/referral; then at the point where people are being assessed for surgery; on the day of surgery (both before and after surgery); and finally during the postoperative follow-up period. The committee agreed people's information needs would change as they passed through this trajectory. It also noted that there was considerable heterogeneity in the amount of information people wanted to receive (particularly around risks) but agreed it was always appropriate that information should be available, even if the person decides they do not want to receive all of it at that stage. The committee agreed it would not be possible or appropriate to list all the information that should be given to people at each stage, particularly as this will differ between individuals, but agreed it was appropriate to set minimum levels that should always be provided. The specific items included in this minimum list were derived from three sources: 1) items identified from the quantitative evidence as being important to a large proportion of people; 2) items identified through the qualitative evidence as being sources of distress if such information was not provided; 3) committee consensus, where it was agreed items would always form part of good practice for discussions with individuals. Additionally, where other review questions in this guideline (such as those on biometry in people with corneal refractive surgery, or bilateral simultaneous cataract surgery) had identified specific issues around patient information needs, it was agreed that it would be appropriate to cross-refer to those sections here, to ensure that there was coherency across the recommendations made for patient information. The committee agreed that, at the point of referral, the main information needs were general (what cataracts are, how they may affect people, how they can be treated), but that, as a person moved in to more specialist care, they should receive more detailed information about their specific risks and potential benefits from surgery to help guide their decision-making. This conversation should also include information about what they will need to do to prepare for surgery, and the expected post-surgical pathway and recovery pattern. Specific information needs were identified for the day of surgery itself, both before (when people should be informed what to expect during the procedure so as to minimise any possible distress), and afterwards (when detailed information should be provided about both what to do and what to expect in the post-surgical period).
Consideration of health benefits and resource use	No health economic evidence was identified for this review question and economic modelling was not prioritised. The committee agreed that none of the items listed should result in it being necessary to increase the total contact time between staff and patients/carers, and therefore there would not be expected to be any increase in resource use.
Quality of evidence	The committee agreed that the overall quality of the evidence was moderate. They agreed that the evidence presented from a 2006 Dutch study was applicable to the UK, as neither the difference in setting nor date would be expected to have a substantial impact on the findings of the research.
Other considerations	Recommendations on the information needs of people during the postoperative recovery period are included in section 13.2 rather than this section, but the committee did also make use of the evidence from this section when drafting those recommendations. The committee agreed that the subgroup of people who lacked capacity to be involved in these discussions themselves required

	specific consideration. They therefore agreed it was appropriate that, when referring to the NICE guideline on patient experience, that particular reference should be given to the recommendations on patient capacity and consent. Additionally, the committee was aware that the NICE guideline on dementia is currently being updated, and the scope for that guideline contains making recommendations on managing comorbidities (including ocular comorbidities) in people living with dementia. The committee agreed it was appropriate to draw attention to this upcoming guidance in the form of a footnote to this recommendation. The committee also noted that people with cataracts may need written information to be given in modified formats (e.g. large print), tailored to their particular visual problems. The committee agreed these issues are appropriately covered in the NICE guideline on patient experience in adult NHS services, and therefore no specific recommendation was necessary.

5.1.7 Recommendations

1. **Give people with cataracts, and their family members or carers (as appropriate), both oral and written information. Information should be tailored to the person's needs, for example, in an accessible format. For more guidance on giving information to people and discussing their preferences, see the NICE guideline on patient experience in adult NHS services, particularly recommendations 1.2.12 and 1.2.13 on capacity and consent[1].**

2. **At referral for cataract surgery (also see section 6.1), give people information about:**
   - cataracts:
     - what cataracts are
     - how they can affect vision
     - how they can affect quality of life
   - cataract surgery:
     - what it involves and how long it takes
     - possible risks and benefits
     - what support might be needed after surgery
     - likely recovery time
     - how vision and quality of life may be affected without surgery.

3. **At the preoperative outpatient appointment, review and expand on the topics in recommendation 2, and give people information about:**
   - the refractive implications of different intraocular lenses (see recommendation 29)
   - types of anaesthesia
   - the person's individual risk of complications during or after surgery (for example, the risk of postoperative retinal detachment in people with high myopia; also see recommendations 17 and 18)
   - what to do and what to expect on the day of cataract surgery

1 The NICE guideline on dementia is being updated, and is due to be published in summer 2018. The dementia guideline update will cover managing comorbidities (including ocular comorbidities) in people living with dementia.

- what to do and what to expect after cataract surgery
- what support might be needed after surgery
- medicines after surgery (for example, eye drops) and medicines that people may be already taking (for example, anticoagulants).
- the refractive implications after previous corneal refractive surgery, if appropriate (see recommendation 13)
- bilateral simultaneous cataract surgery, if appropriate (also see recommendations 37 and 38)

4. On the day of surgery, before the operation, give people information about:

- their position on the list
- what to expect during and after surgery.

5. On the day of surgery, after the operation, give people information about:

- what visual changes to expect
- signs and symptoms of potential complications to look out for
- any restrictions on activities, for example, driving
- possible problems and who to contact
- emergency situations and who to contact
- eye drops
- pain management
- their next appointment and who they will see.

6 Indicators for referral

Cataract surgery is the most commonly performed elective surgery in the UK, with over 300,000 operations performed in England each year over recent years. The clinical and cost effectiveness of cataract surgery (at a population level) is well established in both people with and without ocular comorbidities. In spite of this, there is concern that there is wide variation across the country in commissioning policies for cataract surgery. In some areas, restriction of access to cataract surgery has been introduced by referral thresholds, based only on visual acuity. In England this has led to a reported threefold variation in the number of people having cataract surgery between different areas.

Whilst cataracts are an almost inevitable consequence of ageing, the time at which cataract surgery is performed can vary depending on the visual needs and social circumstances of the individual. In the UK, a majority of patients with cataracts are first diagnosed by their community optometrist, either during a routine check, or on presentation with a visual problem. The decision to refer for surgery requires a careful, informed conversation between clinician and patient, and includes consideration of the surgery itself. A referral to the hospital eye service is often made through the GP after a recommendation from an optometrist, or directly from optometrists. Only patients who would be likely to agree to and benefit from surgery should be referred, to maximise the number of referrals who go on to have surgery, and therefore the efficiency of the hospital eye service.

Limited capacity in the NHS and rising demand from an ageing population has led to prioritisation initiatives in commissioning bodies, some of which are based on clinical criteria and may not consider quality of life factors. However, the variation in prioritisation criteria can lead to inequalities of access, and therefore it is important to understand the evidence base behind any indicators or clinical thresholds for referral.

Visual acuity, both for near and distance, is the most commonly used and most easily quantifiable indicator of visual function. However, in people with a cataract, sole dependency on visual acuity can underestimate visual disability as it does not take into account other symptoms of cataracts, such as glare or reduced contrast sensitivity, which have the potential to significantly impact on a person's quality of life. For example, a patient with a posterior sub-capsular cataract in one eye might have visual acuity of 6/6 but have disabling glare symptoms, preventing driving in bright sunlight and at night.

In many areas of England, priority is given to first-eye surgery, with restrictions on access to second-eye surgery for people who have already had 1 cataract removed. Again, it is important to understand the evidence base behind these decisions, and whether they are clinically justified.

Ultimately, the decision for referral and surgery (for both first- and second-eye surgery) lies in an informed discussion between clinician and patient, and necessitates a balance between clinical measures such as distance visual acuity and other indicators of visual function, clinical need for a clear fundus view (such as for diabetic retinopathy screening or the management over other ocular comorbidities), and also individual requirements for activities such as driving.

6.1 Indicators and thresholds for referral for cataract surgery

6.1.1 Review questions

- What are the indicators for referral for cataract surgery?
- What are the optimal clinical thresholds in terms of severity and impairment for referral for cataract surgery?

6.1.2 Introduction

The aim of this review was to identify the indicators and thresholds for referral for cataract surgery. The review focused on identifying studies that fulfilled the conditions specified in Table 8. For full details of the review protocol, see Appendix C. The main outcomes for this review were visual acuity, visual function and quality of life after surgery.

Table 8: PICO inclusion criteria for indicators and thresholds for referral for cataract surgery

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery for non-trauma related cataracts
Interventions	• Prioritisation criteria/appropriateness frameworks/scores/referral policies • Preoperative visual function, acuity and health-related quality of life
Outcomes	• Indicators for referral for cataract surgery • Conversion rate • Visual acuity • Visual function • Road traffic accidents • Falls • Health-related quality of life • Resource use and costs

Papers were excluded if they:

- were narrative reviews, case studies/reports, commentaries, editorials/letters or opinion pieces.
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- reported studies conducted entirely in non-OECD countries
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

6.1.3 Evidence review

In total, 10,956 references were found from a combined database search for both review questions, and full-text versions of 85 citations that seemed potentially relevant to this topic were retrieved and screened. Eight observational studies (prospective and retrospective cohorts) were included (Bellan et al., 2005; Choi et al., 2008; Frost et al., 2001; Gutierrez et al., 2009; Lash et al., 2006; Lundstrom et al., 2006; Quintana et al., 2009; Tobacman et al., 2003) for indicators for referral. Five studies (4 prospective cohorts and 1 systematic review) were included (Bilbao et al., 2009; Black et al., 2009; Kuoppala et al., 2012; Kessel L et al., 2012; Monestam et al., 1999) for clinical thresholds.

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

6.1.3.1 Description of included studies

The design of included studies is summarised in Table 9 and Table 10. Full details and results are found in the evidence tables (see Appendix E). It was not possible to pool the results of individual studies together due to considerable heterogeneity both in the populations and settings of the studies, and in the referral criteria and thresholds examined, and therefore the results for each study are presented individually.

Table 9: Summary of included studies – indicators for referral

Study & location	Population	Methods
Bellan (2005) Canada Prospective cohort	149 people on Manitoba cataract waiting list who indicated no impairment according to VF14 questionnaire	Cataract surgery followed by assessment of the benefit from surgery according to VF14 questionnaire.
Choi (2008) Korea Retrospective cohort	222 people referred for cataract surgery	Rating of patients based on the RAND/UCLA ratings.
Frost (2001) England Retrospective cohort	2,647 people referred for cataract surgery	Grouping individuals on suitability and requirement for surgery
Gutierrez (2009) Spain Prospective cohort	4,336 people referred for cataract surgery	Rating of patients based on the RAND/UCLA ratings.
Lash (2006) England Prospective cohort	412 referrals for cataract surgery	Referrals outcomes assessed in terms of listing rate and reasons for not listing.
Lundstrom (2006) Sweden Prospective cohort	307 cataract surgery patients	Using the NIKE clinical tool to allocate into indication for surgery groups.
Quintana (2009) Spain Prospective cohort	4,335 people referred for cataract surgery	Grouping patients using a newly developed explicit appropriateness criteria for surgery.
Tobacman (2003) USA Retrospective cohort	793 people referred for cataract surgery	Rating of patients based on the RAND/UCLA ratings.

Table 10: Summary of included studies – thresholds for referral

Study & location	Population	Methods
Bilbao (2009) Spain Prospective cohort	4,356 cataract surgery patients	Grouping patients according to baseline visual acuity
Black (2009) UK Prospective cohort	745 cataract surgery patients	Grouping patients according to baseline visual function
Kessel (2016) Denmark Systematic review	8 studies	Systematic review
Kuoppala (2012) Finland Prospective cohort	90 cataract surgery patients	Grouping patients according to baseline visual acuity and visual function.
Monestam (1999) Sweden	453 cataract surgery patients	Grouping patients using criteria based on visual acuity

Study & location	Population	Methods
Prospective cohort		

6.1.4 Health economic evidence

6.1.4.1 Systematic review of published cost–utility analyses

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts. A total of 4,306 references were retrieved, of which 2 were included for this review question. Summary results for the published studies are included here, with detailed analysis and evidence tables available in Appendix J. This question was also prioritised by the committee for original health economic analysis.

Naeim et al. (2006) conducted an economic evaluation alongside an RCT that enrolled 250 patients with bilateral cataracts eligible for first-eye surgery in whom the predicted probability of improvement in visual function was low. The trial randomised participants to surgery or watchful waiting. The primary outcome measure was the self-reported change in visual function measured using the Activities of Daily Vision Survey (ADVS). The Health Utility Index 3 (HUI-3) instrument was also used to collect data on the health-related quality of life (HRQoL) of participants at enrolment and at the 6-month post-surgery/post-enrolment endpoint.

The Cataract Surgery Index (CSI) was used to assess how likely patients were to benefit from surgery. Patients with a CSI score of 10 points or more are considered to have a low probability (<30%) of improving with surgery. The economic analysis was conducted from a co-payer perspective, which assumed that the costs of spectacles, medication and surgery were shared between the patient and the provider, and non-healthcare-related costs to the patient such as travelling to appointments and loss of working days were also incorporated into the analysis. Results are presented as simple (not incremental) cost and QALY gains for surgical intervention for the entire surgical cohort and for three scoring brackets of the CSI. The cost-effectiveness of surgery was $38,288/QALY. In the subgroup of patients with a CSI score > 11 (< 20% probability of improvement), the cost-effectiveness of cataract surgery was $53,500/QALY. A sensitivity analysis suggests that, if costs increase by 50% or QALY gains reduce by 25%, surgery is not cost effective at a threshold of $50,000 per QALY (although it should be cautioned that this was not an incremental analysis and the threshold is not being applied here to incremental costs and QALYs). The analysis only considers the benefits of surgery as reported at 6 months post intervention.

Rasanen et al. (2006) considered the HRQoL assessment of patients undergoing cataract surgery as a method of prospectively identifying those patients most likely to benefit from the procedure. Three cohorts of patients with bilateral cataract were included: 87 patients in which the first eye was to be operated, 73 in which both eyes were to be operated, and 59 patients who had a history of unilateral cataract removal. The average age (all patients) was 71 years (SD 11 years). HRQoL was measured immediately before and 6 months after surgery using the 15D instrument, which has a Finnish-societal preference-based valuation. The analysis used a secondary care provider payer perspective, with direct medical costs taken from a Finnish clinical patient administration database. It is possible to calculate ICERs by comparing the costs and QALYs between the first eye only and the bilateral surgery group to create a second-eye vs unilateral surgery comparison (see Table 11).

Table 11 Base-case results from Rasanen et al.

	First-eye		Both eyes		Incremental		
	Costs	QALY	Costs	QALY	Costs	QALY	ICER
Mean	€ 1,318.00	0.1605	€ 2,289.00	0.4464	€ 971.00	0.2859	€ 3,396.29

The third cohort, who had a history of first eye surgery and awaiting second eye-surgery, experienced QALY losses after surgery of on average -0.0219. The reasons for this are unclear but the authors suggest that it may be due to patient characteristics. Postsurgical visual acuity data were not included in the study, making further investigation difficult.

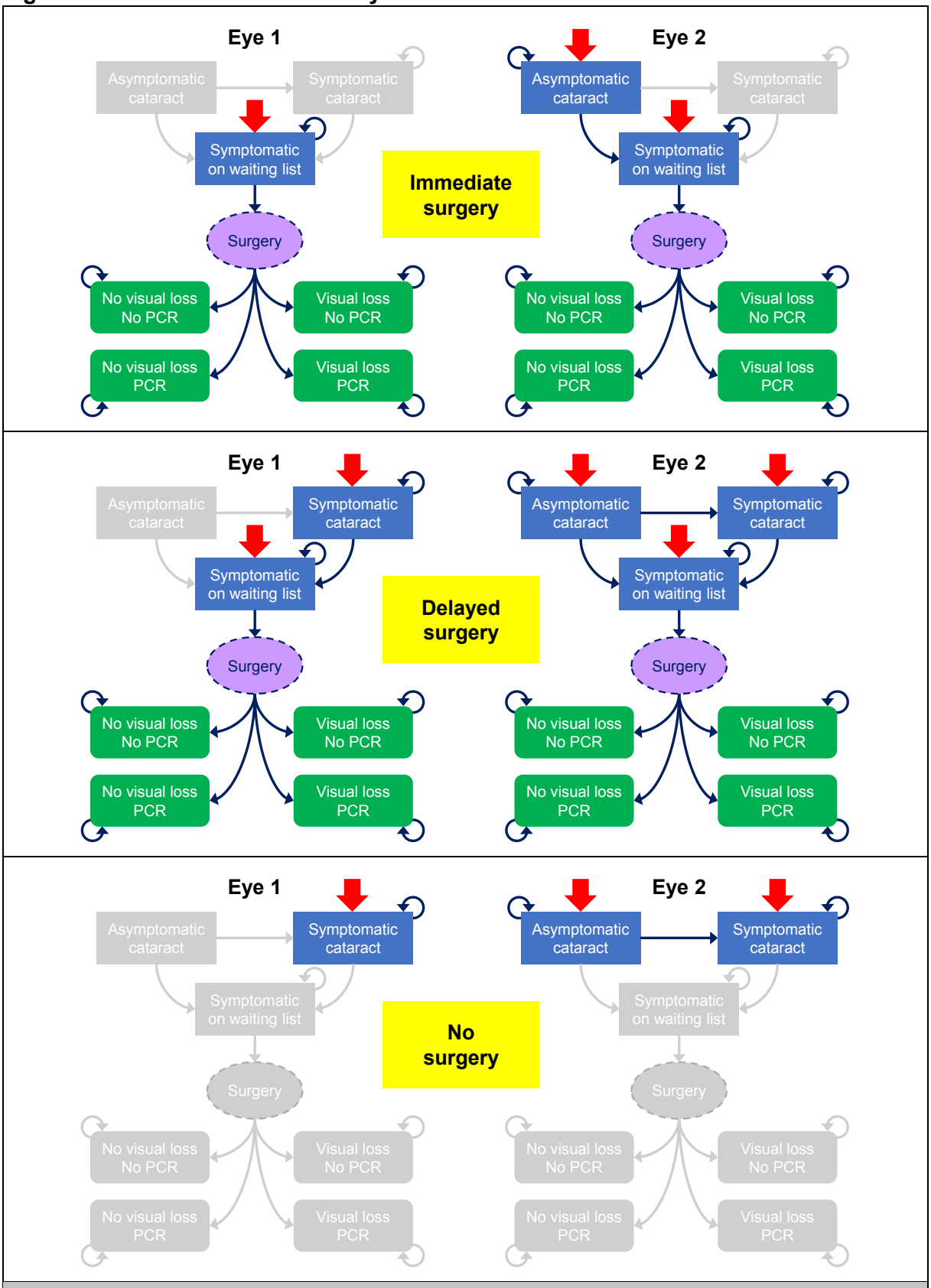
6.1.4.2 *De novo* economic model

Methods

An Excel model was developed that compares 3 strategies: no surgery, immediate surgery, and delaying surgery until visual acuity (VA) reaches a specified threshold. The delayed surgery arm allows for the simulation of different VA thresholds so that the impact on cataract surgery cost effectiveness can be examined. The model differentiates between first and second operated eyes, incorporates visual acuity changes over time in eyes both pre- and-postoperatively, and includes risk factors which influence the visual acuity outcome of surgery. The model includes the cost of surgery including outpatient care, explicit costs of measures to treat and monitor endophthalmitis, posterior capsule opacification (PCO), posterior capsule rupture (PCR) and retinal detachment, and the NHS and PSS costs of support services for people with low vision. Additional background costs associated with increased health service use post-surgery, as detailed by Sach et al. 2010, are included in a sensitivity analysis. A full description of the parameterisation of the model is given in Appendix J.

In this analysis, it was necessary to build a model which might identify the particular characteristics of people with cataracts that can change the expected balance between benefits, harms and costs (see appendix J for the full rationale). The model is not designed to generate ICERs that suggest whether surgery is or is not cost effective. Instead, the model takes into account the available evidence on multiple risk factors and other patient characteristics and generates an estimate of the minimum magnitude of change in HRQoL that would be required to make cataract surgery cost effective, for a person – or a population of people – with specified characteristics.

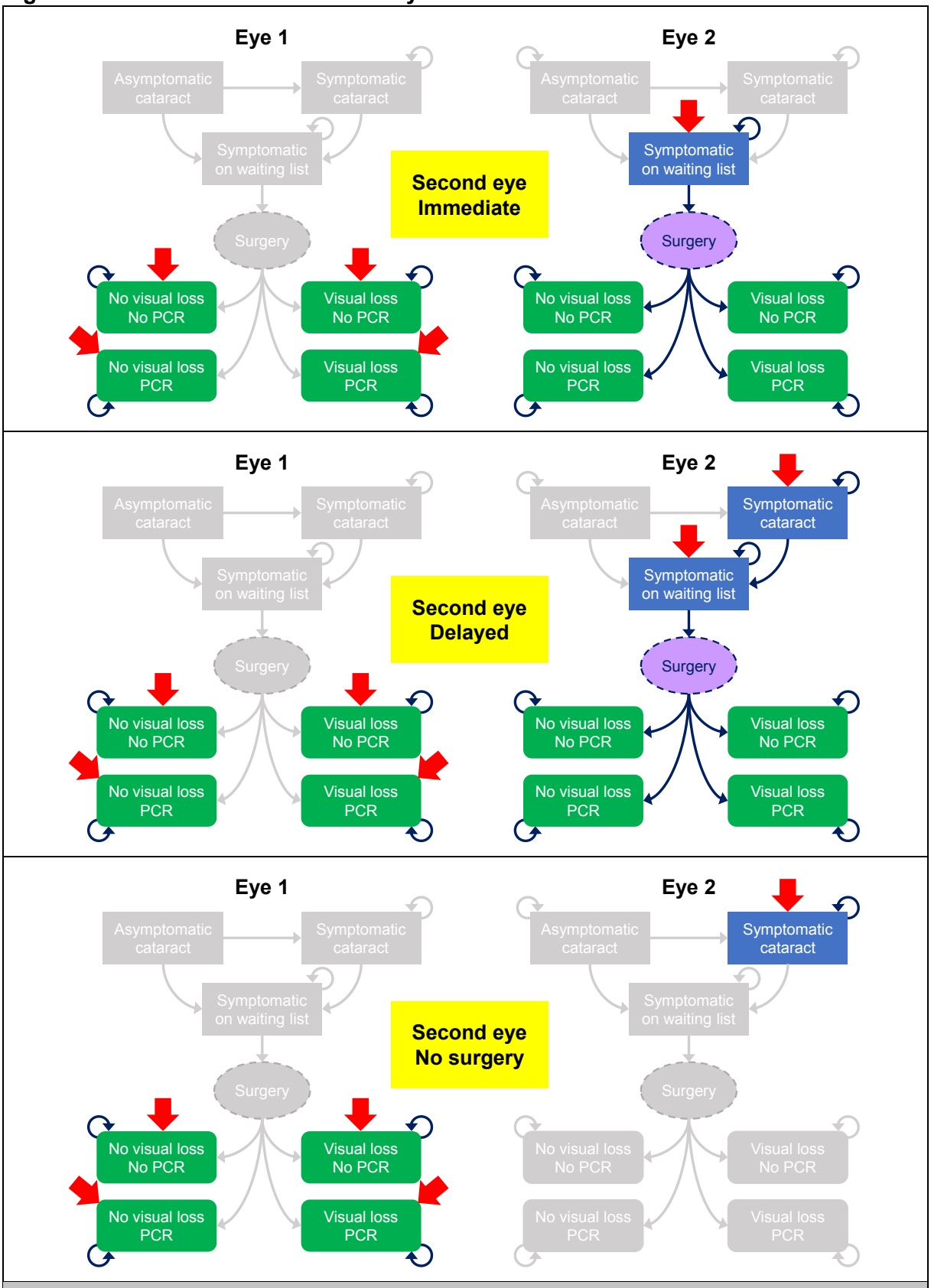
1111 **Figure 1 Model structure for first eyes**



Block red arrows show states in which patients can potentially start the model. 'Surgery' is not a state, but an event resulting in transition to postsurgical states.

1112

1113 **Figure 2 Model structure for second-eyes**



Block red arrows show states in which patients can potentially start the model. 'Surgery' is not a state, but an event resulting in transition to postsurgical states.

1114

Figure 1 depicts how the general model structure is deployed in the 3 strategies simulated for the first-eye surgery decision problem.

- In the case of **immediate surgery**, everyone joins the waiting list for first-eye surgery from the outset. The second eye of these people may be symptomatic (in which case it will also be assigned to the 'waiting list' state, and will receive surgery in the same 3-month cycle as the first eye, or asymptomatic (in which case, it is subject to a probability of developing symptoms as the model progresses).
- In the case of **delayed surgery**, the case will be identical to immediate surgery for anyone presenting with both eyes at or below the acuity threshold determining access. However, if one or both eyes have acuity better than the threshold, they will remain in the 'symptomatic cataract' state until their sight deteriorates to the required degree, at which point they will join the waiting list for surgery. For the second eye, transition from 'asymptomatic cataract' directly to the waiting list is possible if the level of acuity impairment in the eye had already crossed the threshold before the cataract became symptomatic.
- In the case of **no surgery**, the first eye always remains symptomatic until death. The second eye may start as symptomatic or develop symptoms over time; in either event, as with the first eye, it remains symptomatic until death.

The model structure for second-eye surgery is similar, with some slight modifications. It is shown in Figure 2. Regardless of strategy, the first (pseudophakic) eye represents a weighted average of possible outcomes from the initial surgery, with probabilities of each assumed to reflect the average observed across the population. No subsequent transitions are modelled for the first eye (though this does not mean that no deterioration of acuity is simulated for people with 'good visual outcomes'; this categorisation simply reflects the short-term result of the historical surgery). The 'asymptomatic cataract' state is no longer possible for the second eye, as this decision problem envisages people in whom second-eye surgery is being considered, who must have some degree of cataract-related impairment in the eye in question.

- In the case of **immediate surgery**, everyone joins the waiting list for second-eye surgery from the outset.
- In the case of **delayed surgery**, second eyes which meet the acuity threshold will also join the waiting list immediately. However, eyes that have acuity better than the threshold will remain in the 'symptomatic cataract' state until their sight deteriorates to the required degree, at which point they will join the waiting list.
- In the case of **no surgery**, no transitions occur: the first eye remains in its assigned postsurgical category and the second eye remains symptomatic until death.

We based our modelled cohort on the large Royal College of Ophthalmologists' National Ophthalmology Database (RCOphth NOD) study of cataract surgery. Multivariable models using the RCOphth NOD dataset have been published which can be used to calculate the probability of good or poor visual outcome based on patient and eye-related factors. Sparrow et al. (2012) developed a logistic regression model to assess candidate indicators for poor (doubling of visual angle or worse) visual outcome. The model incorporated data from 12 NHS trusts, totalling 406 surgeons across 55,567 cataract operations undertaken between 2001 and 2006, for which postoperative VA outcomes were known for 40,758 (73.3%). All of the models adjusted for preoperative baseline VA as a continuous variable, and for inter-eye correlation by adjusting for paired eyes. The models incorporated the following covariates:

- age
- sex
- any ocular comorbidity
- age-related macular degeneration
- glaucoma

- diabetic retinopathy
- brunescent/white cataract
- high myopia
- corneal pathology
- amblyopia
- uveitis/synechiae
- no fundal view/vitreous opacities
- pseudoexfoliation/phacodonesis
- previous vitrectomy
- previous retinal detachment surgery
- axial length (quintiles)
- pupil size
- inability to co-operate
- unable to lie flat
- any alpha blocker
- tamsulosin, doxazosin, alfuzosin, indoramin, prazosin, terrazosin
- surgeon grade
- and PCR during surgery

Because of the large number of independent variables the models were limited to a main effects approach, and were generated using forward and backwards stepwise methods. The best-fitting visual loss model was one which included older age, short axial length, presence of ocular comorbidity, diabetic retinopathy, small pupil size and PCR during surgery as risk factors. We incorporated this model of clinically significant visual loss into our analysis.

The guideline committee advised that, from a purely pathological point of view, the modelled population should be assumed to have bilateral cataracts (except in the case of unilateral pseudophakia). However, it emphasised that this is not necessarily the same thing as bilateral **symptomatic** cataracts; rather, it is the case that a cataract can always be detected in the fellow eye of anyone with at least one symptomatic cataract.

The model uses a patient perspective for outcomes and an NHS and PSS perspective for costs, in line with *Developing NICE guidelines* (2014). The model includes 6 dimensions of data: baseline HRQoL, visual acuity in each eye, age, the probability of PCR, and the probability of visual loss. The possible combinations of these values runs into the several million, and therefore it is both sensible from the point of view of developing results that are useful to making recommendations, and desirable from a computational workload perspective, to rationalise these data by categorisation. The cross-categorisation across 6 domains results in a matrix of 2,916 unique scenarios, each representing some combination of age, VA in the index eye, VA in the fellow eye, baseline HRQoL, risk of visual loss, and risk of PCR. It may be useful to imagine this matrix as generating a very large number of subgroup analyses, with the model calculating a categorical value of utility-gain for each of the cells in the matrix, which represent each possible combination of variables (the subgroups). For baseline HRQoL, we use natural breaks to characterise low, moderate and good categories as 0.4/ 0.6/ 0.8. For utility gains, we started with the EQ-5D as a template and developed the following categories accordingly:

- A **very small** change is any change less than moving a full category (i.e. less than the EQ-5D can measure in an individual case)
- A **small** change is less than the smallest change possible when moving from a level 3 to a level 2, but greater than the smallest change possible when changing from a level 2 to a level 1

- A **moderate** change is greater than this but less than the smallest change possible when either:
    a) moving from a 3 > 1
    OR
    b) moving from 2->1 in at least TWO separate categories.
- A **large** change is any change larger than this

These criteria equate to utility ranges of:

- Very small = 0.00–0.03
- Small = 0.03–0.06
- Moderate = 0.06–0.10
- Large = >0.10

The full results matrices are published in Appendix J, subappendix Jd.

Results

The model suggests that, in an overwhelming majority of scenarios, **immediate first-eye cataract surgery** is cost effective compared with no surgery, **even if it confers no immediate HRQoL gain**. This is because immediate surgery avoids future QALY losses and costs incurred by leaving the cataract(s) to progress until death. There are very few exceptions to this rule, all of which involve people aged 90 who have no impairment of BCVA (6/6 vision) in the eye for which surgery is contemplated. If such people have **either** very good **or** very poor vision in their other eye, and they are at high risk of **both** PCR and visual loss, they would only be candidates for cost effective surgery if it confers an improvement in their HRQoL that can be classified as at least 'very small' (see appendix J for illustrative definitions).

When comparing immediate with delayed surgery, most people are predicted to benefit from immediate surgery even if it confers no HRQoL gain and, in those cases where a gain of HRQoL is necessary to justify the slightly higher cost of immediate surgery, this benefit only has to be of 'very small' magnitude. However, compared to the immediate vs no surgery comparison, there are a greater proportion of scenarios in which this kind of expectation is necessary:

- In 90-year-old patients, when BCVA in the index eye is unimpaired (6/6) and the risk of PCR and/or a poor visual outcome is high
- In younger patients, the scenarios in which a (very small) gain in HRQoL is needed are all those in which fellow-eye vision is 6/12. In these cases, it is most important to achieve an immediate gain in HRQoL when the risk of poor visual outcome is **lowest**; conversely, when the risk is high, no such gain is necessary. This is because, in this case, the risk only increases as the patient ages; therefore, delaying surgery until they meet a threshold is counterproductive.

For second-eye cases, immediate cataract surgery is shown to be cost effective compared with no surgery in most scenarios, **even if it confers no immediate HRQoL gain**. This is because, as with the first-eye surgery, immediate surgery avoids future QALY losses and costs incurred by leaving the cataract(s) to progress until death. Compared with the first eye, there are slightly more scenarios in which HRQoL gain is necessary to produce an ICER lower than £20,000 / QALY; however, in common with the first eye, all these relate to people aged 90. In most cases, these scenarios also feature a high risk of visual loss. A very similar pattern is shown when comparing no surgery with delayed surgery with an acuity threshold of 6/12: most people are predicted to benefit from immediate surgery even if it confers no HRQoL gain and, in those cases where a gain of HRQoL is necessary to justify the slightly

higher cost of immediate surgery, this benefit only has to be of 'very small' magnitude. All these scenarios relate to 90-year-olds and most feature a high risk of visual loss.

Whilst it was not possible, because of structural constraints, to run any probabilistic sensitivity analyses for the model, some deterministic sensitivity analyses were run. These included simulating a more rapid deterioration of VA in people with cataract; including wider NHS costs that would typically fall outside of the NICE reference case; and modelling an alternative acuity threshold of 6/9 in the delayed surgery arm. The model behaved as expected in these scenarios, with faster progression making immediate surgery more cost effective in all cases, regardless of risk factors. Including wider costs, or changing the acuity threshold to 6/6 increased the margin by which cataract surgery, in either eye, has to improve HRQoL for 90 year old patients with higher risk profiles. A full description of the sensitivity analyses is given in appendix J.

Conclusion

For the majority of patients with symptomatic cataract, it is clearly optimal to offer surgery, and it is not cost effective to delay this until a VA threshold is met. This is true whether for first- or second-eye surgery. For some combinations of characteristics (typically relating to older patients with a high risk of perioperative visual loss), an expectation of improved quality of life is necessary to make surgery cost effective but, in all such cases, the magnitude of anticipated gain need only be 'very small' to justify immediate surgery.

6.1.5 Evidence statements

6.1.5.1 Indicators for referral

6.1.5.1.1 Visual acuity

Low- to high-quality evidence from 4 cohort studies containing 8,452 participants found that people categorised as needing cataract surgery more, using different assessment tools, obtained a greater improvement in visual acuity compared with those categorised as needing surgery less, but could not identify any subgroups in which no gain from surgery was observed:

- High-quality evidence from 1 prospective cohort study containing 3,126 participants found that people rated either necessary or appropriate for cataract surgery had a significantly larger visual acuity gain 6 weeks postoperatively than people rated uncertain or inappropriate.
- High-quality evidence from 1 prospective cohort containing 3,126 participants found that people rated either necessary or appropriate for cataract surgery had a clinically meaningfully higher probability of achieving an improvement in visual acuity of at least the study's defined minimal clinically important difference than people rated uncertain or inappropriate.
- High-quality evidence from 1 prospective cohort study containing 4,336 participants found that people rated as high priority for cataract surgery had a significantly larger visual acuity gain 6 weeks postoperatively than people rated low priority.
- Moderate-quality evidence from 1 retrospective cohort study containing 222 participants found that people rated either crucial or appropriate for cataract surgery had a significantly larger visual acuity gain (LogMAR) 1 year postoperatively than people rated uncertain or inappropriate.
- Low-quality evidence from 1 retrospective cohort study containing 768 participants found that people rated either crucial or appropriate for cataract surgery had a clinically meaningfully higher probability of improvements in visual acuity 4 months postoperatively than people rated uncertain or inappropriate.

6.1.5.1.2 Visual function

Moderate- to high-quality evidence from 3 cohort studies containing 7,684 participants found that people categorised as needing cataract surgery more, using different assessment tools, obtained a greater improvement in visual function (as measured with the VF-14 tool), compared with those categorised as needing surgery less, but could not identify any subgroups in which no gain from surgery was observed:

- High-quality evidence from 1 prospective cohort study containing 3,126 participants found that people rated either necessary or appropriate for cataract surgery had a significantly larger visual function gain 3 months postoperatively than people rated uncertain or inappropriate.
- High-quality evidence from 1 prospective cohort study containing 3,126 participants found that people rated either necessary or appropriate for cataract surgery had a clinically meaningfully higher probability of achieving an improvement in visual function of at least the study's defined minimal clinically important difference than people rated uncertain or inappropriate.
- High-quality evidence from 1 prospective cohort study containing 4,336 participants found that people rated as high priority for cataract surgery had a significantly larger visual function gain 6 weeks postoperatively than people rated low priority.
- Moderate-quality evidence from 1 retrospective cohort study containing 222 participants found that people rated either crucial or appropriate for cataract surgery had a significantly larger visual function gain 1 year postoperatively than people rated uncertain or inappropriate.

6.1.5.1.3 Satisfaction

Moderate-quality evidence from 1 prospective cohort study containing 105 participants found that, of the people who scored the maximum of 100 on their preoperative VF-14 form, a substantial number were found to have subjective complaints about their vision.

6.1.5.2 Optimal clinical thresholds for referral

6.1.5.2.1 Visual acuity

High-quality evidence from 1 prospective cohort study containing 4,356 participants found that people with worse preoperative visual acuity (worse than 6/60) had larger gains in postoperative visual acuity than those with better preoperative visual acuity (better than 6/12).

Very low-quality evidence from a meta-analysis of 3 cohort studies containing 368,644 participants could not differentiate proportions of people with improved postoperative visual acuity between those with better and worse preoperative visual acuity.

Low-quality evidence from 1 prospective cohort study containing 93 participants found that people satisfying a visual acuity criterion for surgery had clinically meaningfully higher odds of postoperative visual acuity improvement.

Low-quality evidence from 1 prospective cohort study containing 453 participants could not differentiate self-reported improvement indices between people with better and worse preoperative visual acuity.

6.1.5.2.2 Visual function

High-quality evidence from 1 prospective cohort study containing 4,356 participants found that people with worse preoperative visual acuity (worse than 6/60) had larger gains in postoperative visual function than those with a preoperative visual acuity (better than 6/12).

Low-quality evidence from a meta-analysis of 2 studies containing 5,569 participants found there was no meaningful difference in the proportions of people with improved postoperative visual function between those with better and worse preoperative visual acuity.

Moderate quality evidence from 1 prospective cohort study containing 93 participants found that people satisfying a visual function criterion for surgery had clinically meaningfully higher odds of postoperative visual function improvement.

6.1.5.2.3 Operation success

Moderate-quality evidence from 1 prospective cohort study containing 745 participants found there was no meaningful difference in proportions of people describing the results of their operation as 'good' or 'excellent' between those with preoperative VF-14 scores <94.5 and ≥94.5, or between those with preoperative VF-14 scores <87.8 and ≥87.8

6.1.5.3 Health economic evidence

6.1.5.3.1 Published cost–utility analyses

One partially applicable CUA with serious limitations suggests that cataract surgery may be cost effective even when there is low expectation of visual acuity gain. The degree of uncertainty in this finding is significant, and no incremental analysis was performed. One partially applicable CUA with serious limitations suggests that, based on a prospective assessment of possible HRQoL gain following surgery, cataract surgery may be cost effective if the patient has bilateral cataracts and the intention is to operate on both eyes, but uncertainty in these findings is significant.

6.1.5.3.2 Original model

One directly applicable original health economic analysis with potentially serious limitations suggests that:

1) Offering first-eye cataract surgery is cost effective compared with no surgery in almost all cases even if it confers no immediate HRQoL gain, because future costs of low vision and QALY losses are prevented.
2) When compared with delayed surgery (waiting until the first-eye acuity drops to 6/12), most people are predicted to benefit from immediate surgery even if it confers no immediate HRQoL gain, although there are more cases where a 'very small' gain of HRQoL is necessary to justify the slightly higher cost of immediate surgery.

For second eyes:

1) Cataract surgery is cost effective compared with no surgery in most scenarios even if it confers no immediate HRQoL gain.
2) Compared with delayed surgery, most people derive cost-effective benefit from immediate surgery even if it confers no HRQoL gain and, in older, higher-risk cases where a gain of HRQoL is necessary to justify the slightly higher cost of immediate surgery, this benefit only has to be of 'very small' magnitude (see Appendix J).

The model results were somewhat sensitive to the inclusion of 'unrelated' costs after surgery for first and second eyes, and the assumed rate at which visual acuity declines in symptomatic eyes.

6.1.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that, whilst visual acuity is still commonly used to decide whether cataract surgery is needed, it is a crude measure that will often fail to detect other vision problems that may justify surgery (for example, glare, loss of colour vision). The committee agreed that the best possible decision-making aids would be

	measures of pre- and postoperative vision-related quality of life, which could be used to quantify the impact of surgery for the person, and identify any groups of people who do not gain in quality of life after surgery. However, it noted that most existing prioritisation criteria were based primarily on visual acuity and visual function (usually measured using the VF-14), which capture only part of the impact of a cataract on quality of life.
Trade-off between benefits and harms	The committee noted 2 primary harms that could result if there was an increase in the number of people being referred for surgery. Firstly, increased referral rates could lead to people without significant visual problems having surgery and subsequently experiencing a reduced quality of life where the benefits of surgery are not enough to balance the risks. The committee discussed this scenario and agreed that this is unlikely to be problematic provided people were appropriately informed about the risks as well as benefits of surgery. Secondly, if a significant increase in the number of people having surgery occurred, this could put pressure on capacity in the system. The committee discussed this and agreed that, whilst it was possible there could be a small increase in numbers in the short term, this would be unlikely to lead to significant long-term changes as most people referred earlier would have been likely to have their condition worsen to the point of needing surgery later, and therefore this would only be a change in the timing of the surgery, not in the overall number of procedures taking place. The only exception to this would potentially be in particularly elderly individuals, where the expected rate of mortality before reaching the threshold may mean a meaningful proportion of people never have surgery. Committee members also noted that it was their experience that many surgeons at present were not following thresholds for visual acuity unless they were strictly policed, and that this practice would lower the risk of a sudden influx of new people having surgery. The committee also noted that, when undertaking watchful waiting of patients, complication rates increase with increasing severity of cataract. It noted that, whilst not everyone gets worse (as many are stable), for those who do, this effect can be substantial and increases the risks of surgery. In the absence of the ideal data, the committee agreed that the emphasis should be placed on patient–healthcare professional discussions regarding the effect the cataract is having on the person's quality of life. The committee agreed that such discussions should be used to inform people with cataracts of the risks as well as the benefits of surgery. A willingness on behalf of the person with cataracts to proceed with surgery following such a discussion provides evidence that the person's visual problems are having a significant impact on their quality of life to the extent that they felt that the potential benefits of surgery outweigh the risks. The committee agreed that a structured discussion should, at minimum, contain how the cataract is currently affecting the person's quality of life, the risks and benefits of surgery, and what may be expected to happen if the person chooses not to have surgery.
Consideration of health benefits and resource use	The committee considered that the published economic evidence presented had underestimated the costs associated with some key parameters. It noted that both studies underestimated the costs of endophthalmitis, which could require several follow-up appointments and so incur further costs. No studies reflected the possibility that progression of infection can lead to eye removal, which although rare would incur significant HRQoL losses. However, the committee also discussed that endophthalmitis case numbers could have reduced since 2006/7 due to the common use of prophylactic antibiotics, and

that this would need to be reflected in the appropriate transition probabilities in any new models. The cost of this prophylactic treatment has also reduced over time because of the wider availability of eye-drop formulations.

The committee discussed the characteristics of the patient cohorts included in the models, noting that in both studies there was no consideration of the need to use general anaesthesia for some patients, which would increase the cost of the procedure for more complex cases – some of the same cases with low predicted probability of improvement in the Naeim (2007) study.

The committee recognised that adverse events in cataract surgery involves a complex interplay of risks, with some complications increasing the likelihood of future complications. For example, patients who experience a posterior capsule rupture (PCR) during surgery are more likely to experience a retinal detachment, and retinal detachment is more likely in endophthalmitis, which is itself more likely in patients who have experienced PCR. The risk assessment of patients before surgery with regard to these adverse events may result in a decision to delay surgery, and no published models considered this possibility.

The committee was presented with an original economic analysis that estimates the magnitude of utility gain needed for cataract surgery to be cost effective given multiple risk-factors for visual loss. The model compared three strategies – no surgery, immediate surgery, and delayed surgery (to a 6/12 acuity threshold). In the majority of model simulations, cataract surgery for first- or second-eye surgery was cost effective compared with no or delayed surgery even if it does not generate immediate HRQoL benefit, as future costs and QALY losses were avoided by performing surgery. Because the model generates a large series of matrices for each strategy, the committee also reviewed several exemplar output profiles which illustrated the categorisation of risk levels for visual loss and PCR, and also categories of baseline HRQoL.

The committee discussed that the model was not a decision-making tool for individual cases and that it was inappropriate to use the matrices generated by the model to cross-check with individual patient data when deciding to refer for surgery. Rather, the model was good evidence to support a commissioning strategy that is not based on visual acuity thresholds alone, but that takes into account the relative benefits, risks, harms and costs of offering surgery. To that end, the committee noted that, for the vast majority of cases in the simulated cohort (even those examples with many risk factors for poor visual outcome), immediate referral for surgery once cataract is symptomatic only required very small gains in HRQoL in order to be cost effective. This was independent of whether the surgery is for the first eye or the second eye. The committee was presented with some examples of where surgery required some degree of immediate HRQoL benefit in order to be the cost effective strategy compared to delayed surgery and noted, for example, that this was the case for older (90yrs) patients with high risk of PCR and visual loss. However, in these cases, the committee agreed that delayed surgery would still not be justified, because the lower life expectancy of 90-year-olds means that a nontrivial proportion of the cohort will die before they would qualify for surgery, meaning that they experience avoidable morbidity from their cataract before death as a result of the threshold.

The committee noted that one issue with the modelling approach was that some combinations of factors created by the model were unlikely in a clinical setting – for example, in a person of 90yrs of age with 6/6 vision in the index eye and worse acuity in the fellow eye, the fellow eye would become the index eye and be operated on first. However, the committee noted that these examples still had value in illustrating

	that surgical thresholds are not optimal, given that even 6/6 eyes benefitted from surgery because future QALY losses and costs of low vision were prevented. The committee concluded that visual acuity thresholds, or limits on second-eye surgery, were likely to incur avoidable QALY losses in most cases, and could be shown to increase longer-term costs by raising the demand for low vision services. The committee therefore agreed it was appropriate to make a clear recommendation that visual acuity thresholds should not be used as a criterion to restrict access to cataract surgery. The committee agreed it was appropriate to distinguish between effects on overall vision (which are an important part of the decisions making process) and visual acuity, which was been shown not to be effective as a decision-making criteria. The committee discussed the likely resource and capacity impacts of recommending immediate referral, particularly the increased demand for surgery and associated pressures on capacity. The consensus of the group was that this would likely be a short-term increase in demand as those people with visual acuity below thresholds (in trusts where they currently apply) would move to waiting lists, but that after that initial increase there would be a return to a steady state. The original model was not designed to provide a dynamic simulation of these potential concerns. The committee discussed the difficulty inherent in contextualising the categorical utility-gain estimates generated by the model with reference to HRQoL instruments such as EQ-5D and VFQ-UI and agreed there was a need for future research into how HRQoL changes can be best captured in people with cataract. A research recommendation was therefore made to look at validating quality of life instruments in a population undergoing cataract surgery. The committee noted that this work represented a step forward in understanding the costs involved in cataract surgery and its most common complications. With reference to the model parameters, the committee agreed that the model represented a detailed costing of cataract surgery, which improved on other models with NHS contexts. Some rare, but potentially high-cost complications which can have life-long effects, such as rare cases of blindness caused by haemorrhage, or iatrogenic glaucoma as a consequence of unresolved CMO, or exceptional cases of endophthalmitis which require evisceration of the eye, could not be included because of data availability. The committee discussed that, while these events did indeed incur additional costs which could be described, they were difficult to predict and so rare that, from a whole-population standpoint, their impact on the cost effectiveness of surgery would likely be insignificant. The natural history of cataract was discussed at length with the group, particularly the very limited evidence base from which to draw data on how visual acuity changes over time in patients with symptomatic cataract, and how surgery might change this trajectory. Despite these limitations, the committee agreed that the model represents a step forwards in attempting to model visual acuity changes pre-and postoperatively in pseudophakic and phakic eyes, and therefore the lifetime visual consequences of the different strategies considered. The committee agreed that it was appropriate to consider the visual acuity change rates used in the model as representing likely extreme scenarios, and that, whilst the true rate of decline could not reliably be defined without larger, long-term datasets and incorporation of cataract morphology data, it was reasonable to assume it was somewhere within the range modelled.

	Moreover, the base-case value used was at the conservative end of the spectrum; if the true average rate of decline is faster, surgery would only become even more cost effective.
Quality of evidence	The committee noted that the evidence presented was largely in line with current clinical opinion. It noted that no relevant studies were identified to inform a distinct tool or set of criteria that could be used to determine a threshold for cataract surgery. In particular, whilst many papers found that people rated less appropriate for surgery had smaller gains after surgery, even in the least appropriate group there were still statistically significant postoperative gains. It agreed that the evidence did not support the use of visual acuity measurements as a threshold indicator for surgery. No studies were able to identify a group of patients by visual acuity at baseline who did not improve after surgery. The committee discussed and agreed that the various prioritisation tools presented were often primarily dependent on a visual acuity threshold. It noted that consideration of the risk–benefit transaction involved in offering surgery was missing (for example: a person ranked 'appropriate' using the tool may decide, after consultation, that they did not want to go ahead with the procedure, whilst a person ranked 'inappropriate' may have other vision problems not fully captured by the tool which mean they would benefit from and want surgery). The committee agreed that the VF-14 tool does not appear to be accurate in determining whether someone requires surgery. It suggested that this may reflect the fact that the validation cohort for the VF-14 tool was undertaken long before phacoemulsification surgery was available. The committee noted that the outcomes of surgery are now very different compared with when the tool was validated and this may account for its lack of sensitivity, particularly at the top end of the scale. It noted that even people with the best possible preoperative score on the VF-14 consistently reported postoperatively that their preoperative symptoms were sufficient to justify surgery. The committee noted that the majority of the evidence only consisted of 2 outcome measurements, one before and one after surgery, and that this left gaps in the evidence base. In particular, there was no measurement of how the benefits of surgery persist over time and no data on outcomes for people not having surgery, such as any decline in their vision or quality of life before surgery at a later time point.
Other considerations	The committee agreed that, on first inspection, it may appear somewhat counterintuitive that there are tools which are able to identify groups of people who will gain more from surgery than others, but that surgery is still cost-effective in all the subgroups. However, the committee agreed this was because the current tools are not sensitive enough to be able to detect specific small subsets of people who may exist where the costs and harms of surgery outweigh the benefits. The committee noted that, in certain places in the country, there are issues with a lack of access to optometry services, and this could result in people who would benefit from surgery not being identified. However, this was agreed to be a broader structural problem, and not one that could be fixed or improved by any recommendations around the thresholds used for referral. The committee also noted that, whilst evidence was presented linking preoperative visual acuity and visual function to postoperative visual acuity and visual function, no such data were available on the more relevant question of the link between preoperative quality of life and postoperative quality of life. Therefore, the committee agreed to make a research recommendation in this area.

6.1.7 Recommendations

6. **Base the decision to refer a person with a cataract for surgery on a discussion with them (and their family members or carers, as appropriate) that includes:**
    - how the cataract affects the person's vision and quality of life
    - whether 1 or both eyes are affected
    - what cataract surgery involves, including possible risks and benefits
    - how the person's quality of life may be affected if they choose not to have cataract surgery
    - whether the person wants to have cataract surgery.

7. **Do not restrict access to cataract surgery on the basis of visual acuity.**

6.1.8 Research recommendations

1. **What is the association between preoperative vision- and health-related quality of life on postoperative vision- and health-related quality of life, and self-reported postoperative improvement?**

Why this is important

In contrast to the data linking preoperative visual acuity and visual function with postoperative visual acuity and visual function, there is a lack of evidence on the association between preoperative vision- and health-related quality on postoperative outcomes and levels of satisfaction for people having cataract surgery. This makes it difficult either to identify those groups of individuals who may achieve the largest gains from surgery, or to provide people with accurate information about what their potential gains may be. Robust information around the link between preoperative patient characteristics and outcomes would be useful both for prioritisation of surgery, and to help better inform individuals about the levels of gain they may individually expect to get from surgery.

2. **What vision-specific quality of life measures best capture visual changes in a population with cataracts?**

Why this is important

Although visual acuity is still commonly used to decide whether cataract surgery is needed, it is a crude measure that will often fail to detect other vision problems that may justify surgery (for example, glare and loss of colour vision). The best possible decision-making aids would be measures of preoperative and postoperative vision-related quality of life, which could then be used to identity groups of people who do not have an improvement in quality of life after surgery. However, most prioritisation criteria are based primarily on visual acuity and visual function (usually measured using the VF-14), which capture only part of the impact of a cataract on quality of life. The development and validation of suitable vision-specific quality of life measures would aid the decision-making process for cataract surgery, and help to accurately quantify the quality of life gains that may be expected from surgery.

7 Preoperative assessment and biometry

The current methods to remove a cataract are now very reliable with great reproducibility. A key component of determining a successful outcome is the ability to calculate the power of the lens implant used to replace the natural lens.

The refractive power of the human eye is dependent on three factors, the power of the cornea, the power of the lens and the length of the eye. During cataract surgery a replacement intraocular lens (IOL) is inserted. By knowing the power of the cornea and the axial length of the eye, it is possible to calculate the power of this replacement lens to give the desired refractive outcome.

Biometry is the process of measuring the corneal power and length of the eye. Inaccuracy in either of these measurements will lead to an unpredicted postoperative refractive error.

Corneal power accounts for about 2/3 the total power of the eye and errors in calculation will have a significant effect on the refractive outcome. Corneal power is calculated from measurements made by a keratometer or by a corneal topographer. The calculation of corneal power is based on the curvature (steepness) of the cornea. In keratometry, assumptions are made of a fixed relationship between the front and back corneal surfaces and its uniform spherical shape when making this calculation. This relationship between corneal surfaces is particularly altered during corneal refractive surgery. Some corneal topographical methods measure the anterior and posterior radii of corneal curvature as well as corneal thickness and use these to calculate corneal power.

The accuracy of axial length measurement is crucial in IOL power calculations. A 1mm error in measurement can lead to an equivalent power error of 3.00D. The axial length of the eye may be measured by ultrasound (contact or immersion) or by optical means. Ultrasonography Amplitude scan (A-scan) measures the time taken for an ultrasonic pulse to travel from the cornea to the retina and from this calculates the distance travelled between the two points. Optical methods use partial coherence laser tomography, calculating the time taken for infra-red light to travel from the cornea to the retina and using and interferometry principle to calculate distance between the two.

Once the measurements of the eye have been made, the power of the replacement intraocular lens can be calculated. The formulas for these calculations are generally incorporated into the biometry equipment software and include one or more constants which are specific for a particular lens. They are supplied by the lens manufacturer but may be refined or optimised by a surgeon, taking into account their previous surgical results.

The accuracy and consistency of biometry is dependent on the operator, the individual equipment and the appropriateness of the formulas used, all of which contribute to accuracy and therefore to the refractive outcome of surgery

Optimal biometry is critical to the success of the cataract surgery in terms of the actual refractive outcome being congruent with the required refractive outcome. It is critical therefore that the person undertaking the biometry is competent to undertake the procedure, and a competence framework has been developed by the ophthalmic professional organisations and is available from: https://www.rcophth.ac.uk

Risk Stratification

Risk stratification is a tool for identifying or predicting which patients are at high risk of complications, in this case in cataract surgery. By analysing a large database of patients undergoing cataract surgery and the incidence of complications and their outcomes, it has been possible to determine which patient characteristics and what preoperative co-

morbidities are likely to be associated with per- and postoperative complications and a poor visual outcome.

Risk stratification tools can be used to alert the surgeon to potential complications and poor outcomes and therefore be able to more accurately counsel the patient and arrange for the cataract surgery to be performed by surgeons with the appropriate skills.

Risk stratification is also an important component of surgical audit, allowing more accurate assessment and benchmarking of outcomes.

7.1 Biometry techniques

7.1.1 Review question

- What is the effectiveness of different techniques for undertaking biometry?

7.1.2 Introduction

The review focussed on identifying studies that fulfilled the conditions specified in Table 12. For full details of the review protocol, see Appendix A. The main outcome for this review question was the predictive accuracy of the different techniques, assessed by deviations from the predicted refractive outcome expressed as a spherical equivalent. As suggested by Gale et al. (2009), a benchmark standard of 85% of individuals achieving a final spherical equivalent within 1.00 dioptre of the predicted refraction and 55% of individuals within 0.50 dioptres was used to evaluate the clinical relevance of the review findings.

Table 12: PICO inclusion criteria for the review question on biometry techniques

Population	Adults (18 years and over) undergoing biometry prior to phacoemulsification cataract surgery with intraocular lens implantation
Interventions and comparators	**Ultrasound biometry vs. optical biometry (axial length)** • Immersion ultrasound. Examples: immersion ultrasound A-scan (Canon KU-1 IOL measurer), immersion B-guided • Contact/applanation ultrasound (contact A-mode). Examples: Grieshaber Biometric System, VPLUS A/B scanner • Optical biometry. Examples: partial coherence laser interferometry (optical or ocular) coherence biometry, laser Doppler interferometry, IOLMaster (Carl Zeiss), Lenstar LS900, optical low-coherence reflectometry (OLCR) optical biometer, laser interference biometry **Keratometry vs. topography (corneal curvature)** • Manual keratometry • Automated keratometry Examples: IOLMaster, autokeratometer/Topcon KR-7100, partial coherence interferometry keratometer, videokeratography • Topography. Examples: Pentacam Scheimpflug, Orbscan Topography System
Outcomes	• Deviation from predicted refractive outcome expressed as a spherical equivalent • Resource use and cost

Randomised controlled trials (RCTs) comparing different biometry and keratometry techniques in adults undergoing phacoemulsification cataract surgery to predict the accuracy of postoperative refraction were included. Papers were excluded if they:

- were guidelines/health technology assessment reports, narrative reviews, case studies/reports/series, reliability studies, diagnostic accuracy studies, non-comparative studies
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- focused on combination surgical procedures, that is cataract surgery in tandem with other surgical procedures (for example, phacotrabeculectomy, canaloplasty, Descemet's stripping automated endothelial keratoplasty)
- compared biometry techniques with no biometry only or standard care that was not specified
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

Protocol deviation

Only one RCT published in 1995 comparing standard keratometry and corneal topography on 46 people undergoing phacoemulsification cataract surgery was identified (Antcliff et al., 1995). The Guideline committee noted that keratometry techniques are routinely used as current standard practice in the NHS, while topography which requires greater expertise (training) and time is used in specific circumstances, such as for individuals with a history of corneal refractive surgery that results in an increased risk of postoperative refractive errors stemming from difficulties in estimation of corneal power. Therefore, the committee agreed that it would be useful to further consider observational evidence comparing keratometry techniques and topography only within this specific subgroup. Two observational studies comparing keratometry with topography in individuals with a history of corneal refractive surgery undergoing phacoemulsification cataract operations were identified.

7.1.3 Evidence review

In total, 18,080 references were found for a combined database search for all 4 related review questions on biometry and postoperative refractive errors, with 315 articles ordered for full-text review. Five unique RCTs were identified for the comparison of ultrasound and optical biometry (Fontes et al., 2011; Kolega et al., 2015; Naicker et al., 2015; Rajan et al., 2002; Raymond et al., 2009). One RCT was identified for the comparison of keratometry and topography (Antcliff et al., 1995), while two retrospective case series were identified for this comparison in the specific subgroup of individuals undergoing phacoemulsification cataract surgery with a history of corneal refractive surgery.

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

7.1.3.1 Description of included studies

Details of the included studies are found in the evidence tables (see Appendix C).

7.1.3.1.1 Ultrasound (immersion and contact) and optical biometry to measure axial length

The 5 RCTs including a total of 588 participants (629 eyes; range n=40 to 200) were carried out in England (Rajan et al., 2002), Australia (Raymond et al., 2009), Croatia (Kolega et al., 2015), Brazil (Fontes et al., 2011) and Malaysia (Naicker et al., 2015). Only 1 trial included multiple eyes per participant (Fontes et al., 2011). Baseline characteristics of participants across all studies included mean ages ranging from 67 to 74 years (only age range of 60 to 84 years was reported by Kolega et al., 2015), similar distributions of male and female (57% to 60% female were reported in 4 studies; not reported by Rajan et al., 2002) and mean axial lengths ranging from 23.22mm to 23.45mm (reported in 3 studies; Naicker et al., 2015 specifically excluded people with axial lengths <20mm or >25mm while Kolega et al., 2015 provided no details of this characteristic). With the exception of the study conducted by Raymond et al. (2009), the other 3 trials specifically excluded participants with ocular pathologies that may result in poor visual prognosis. Only Naicker et al. (2015) provided information on specific diagnosis using the Lens Opacities Classification System III (LOCS III), while Raymond et al. (2009) provided details of the types of cataracts that were observed in the sample.

Four trials randomised participants to partial coherence laser interferometry (IOLMaster; Fontes et al., 2011; Kolega et al., 2015; Rajan et al., 2002; Raymond et al., 2009), while Naicker et al. (2015) examined optical low-coherence reflectometry (Lenstar) in its optical biometry group. Two studies examined immersion ultrasound biometry (Fontes et al., 2011;

Naicker et al., 2015), while the other 3 trials focused on applanation or contact ultrasound biometry (Kolega et al., 2015; Rajan et al., 2002; Raymond et al., 2009). Only Kolega et al. (2015) did not provide details of the preoperative assessments/assessors. The remaining 4 RCTs highlighted that the persons undertaking the biometry were experienced, with only Naicker et al. (2015) quantifying the years of experience as a clinical technician (4 years); other studies specified experienced biometrist (Rajan et al., 2002), experienced ophthalmologist (Fontes et al., 2011) and senior orthoptist (Raymond et al., 2009). With the exception of the study conducted by Raymond et al. (2009), these other 3 trials used the same individual to assess both biometry techniques.

Keratometric measurements were standardised in 2 studies (Naicker et al., 2015; Raymond et al., 2009). Rajan et al. (2002) and Kolega et al. (2015) used the Javal keratometer and Righton Speedy-K type automated keratometer respectively for the ultrasound group only, while Fontes et al. (2011) did not provide any details of keratometric measurements. Four studies used the same formula for both biometry techniques (Hoffer Q – Naicker et al., 2015; SRK-T and same intraocular lens (IOL) constant – Rajan et al., 2002; Holladay I – Fontes et al., 2011, Holladay II – Kolega et al., 2015), while Raymond et al. (2009) used the SRK-T formula and manufacturer-recommended constant for the optical group and the SRK-II formula and IOL manufacturer-recommended constant for the ultrasound group. Four studies did not provide any details of IOL constant selection and/or optimisation (Fontes et al., 2011; Kolega et al., 2015; Naicker et al., 2015; Rajan et al., 2002).

All phacoemulsification cataract surgery was undertaken by the same surgeon for 3 studies, while 2 and 12 different surgeons performed operations in the studies conducted by Kolega et al. (2015) and Raymond et al. (2009) respectively. Postoperative refractive assessment varied from up to 2 weeks (Fontes et al., 2011), 5 weeks (Raymond et al., 2009), 6 weeks (Kolega et al., 2015) and 2 months (Naicker et al., 2015; Rajan et al., 2002). Only 2 studies provided details of the methods employed to assess postoperative refraction: autorefractor confirmed with subjective refraction (Rajan et al., 2002) and mixture of subjective refraction and autorefractor conducted by community ophthalmologists and optometrists as per standard practice (Raymond et al., 2009).

The quality of the evidence ranged from very low to low (see Appendix D for the GRADE tables and Appendix E for the forest plots).

7.1.3.1.2 Keratometry (manual and automated) and topography to measure corneal curvature

One RCT comparing standard keratometry (details not provided) and topography (3mm zone keratometric equivalent readings using the Eyesys Corneal Analysis System) in 46 participants (46 eyes) undergoing phacoemulsification cataract surgery with no specified history of corneal refractive surgery was carried out in England (Antcliff et al., 1995). Individuals who had fundal lesions sufficient to reduce postoperative acuity and accuracy of refraction or were unable to undergo the keratometry techniques were excluded. Reported baseline characteristics were limited to mean age of 74 years (range 32 to 92) and proportion of women (34; 73.9%). Biometry measurements for all patients were standardised using the A-scan biometer and the SRK-II formula was used to calculate the IOL power. No further details of the preoperative assessment were provided. Two surgeons performed uncomplicated phacoemulsification cataract surgery with implantation of the same type of 5mm posterior chamber lens in the capsular bag. Postoperative refraction was carried out 3 months after surgery by a “masked” investigator but no further details were provided. The quality of the evidence was low (see Appendix D for the GRADE tables and Appendix E for the forest plots).

Two retrospective case series conducted in the USA (Canto et al., 2013) and South Korea (Kim et al., 2013) compared automated keratometry (IOLMaster) and topography (TMS or Pentacam) in a total of 80 people (93 eyes) with a history of corneal refractive surgery who had phacoemulsification cataract surgery. Kim et al. (2013) specifically included people who had corneal refractive surgery for myopia. The mean ages were 52.4 and 60 years, with a

greater proportion of men included in Canto et al. (2013)'s study (n=22/33) compared with an even distribution of men and women in the Kim et al. (2013) study (22 men and 25 women). The mean duration between refractive and cataract surgery was reported by Kim et al. (2013) to be 8.67 years (SD 5.45, range 1 to 16). The mean axial length was only reported by Kim et al. (2013) to be 27.75 mm (SD 2.19). Biometry measurements were only standardised by Canto et al. (2013) using the IOLMaster, while Kim et al. (2013) used immersion ultrasound for the keratometry group and the IOLMaster for the topography group. The SRK/T formula was used for all groups in both studies, but neither study provided details of IOL constant optimisation. Uneventful phacoemulsification cataract surgery was performed by 8 surgeons with 4 IOL models in Canto et al. (2013), while 1 surgeon and 1 IOL model were reported in the study by Kim et al. (2013). Canto et al. (2013) did not provide details of the timing of the postoperative refraction assessment, while Kim et al. (2013) noted that these measurements were undertaken 2 months following surgery. The quality of the evidence was very low (see Appendix D for the GRADE tables and Appendix E for the forest plots).

7.1.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which none were retained for this review question. Health economic modelling was not prioritised for this review question.

7.1.5 Evidence statements

7.1.5.1 Ultrasound (immersion and contact) and optical biometry to measure axial length

Low-quality evidence from 5 RCTs containing 588 participants found no statistically significant between group differences in mean absolute prediction errors for ultrasound (including separate subgroup analyses for immersion and contact) compared with optical biometry in people undergoing phacoemulsification cataract surgery. Similarly, no statistically significant between group differences were observed in the proportion of individuals achieving postoperative refraction within various predicted ranges (<0.50 dioptres, <1.00 dioptre, <1.50 dioptres and <2.00 dioptres). Both the ultrasound and optical biometry groups demonstrated similar levels of achieving the standard benchmarks for individuals attaining a final spherical equivalent within 1.00 dioptre of the predicted refraction (90.7% with ultrasound biometry vs. 93.6% with optical biometry) and within 0.50 dioptres (68.2% with ultrasound biometry vs. 72.7% with optical biometry).

7.1.5.2 Keratometry (manual and automated) and topography to measure corneal curvature

Very low- quality evidence from 1 RCT containing 46 participants found no statistically significant between group differences in mean absolute prediction errors for standard keratometry compared with corneal topography in people undergoing phacoemulsification cataract surgery. Statistically significant between group differences were observed in the proportion of individuals achieving postoperative refraction within 0.50 dioptres of the predicted refraction (34.8% with standard keratometry vs. 69.6% with corneal topography).

Overall, very low-quality evidence from 2 retrospective case series containing 186 participants showed smaller mean prediction errors and/or greater proportions of individuals within 0.50 dioptres of the predicted refraction in the topography group compared with the automated keratometry group in people undergoing phacoemulsification cataract surgery with a history of corneal refractive surgery. However, the direction of effect and/or whether statistically significant between group differences were observed depended upon the type of topography machine (e.g. Scheimpflug or Orbscan), topography reading (e.g. true net corneal power, equivalent K, 2.0mm or 4.0mm diameter central zone of the total mean

power, simulated K), formulas (e.g. SRK-T, Haigis-L, American Society of Cataract and Refractive Surgery estimation) and point estimate (e.g. mean prediction errors, mean absolute prediction errors) used.

7.1.5.3 Health Economic Evidence

No health economic evidence was identified for this review question.

7.1.6 Evidence to recommendations

Relative value of different outcomes	The Guideline committee agreed that the critical outcome for decision making was deviation from predicted refractive outcome, while resource use and costs were considered to be important. The committee noted that tolerances in axial length and corneal curvature measurement and formulas may impart a total refractive error of up to 1.00 dioptre. The committee noted that axial length is a major contributor to prediction errors such that for every 1.0mm measurement error, 3.00 dioptres refractive outcome error is introduced. However, the ratio for keratometry is 1:1, such that for every 1.00 dioptre corneal curvature error, 0.90 to 1.00 dioptres refractive outcome error is introduced.
Trade-off between benefits and harms	The committee noted that optical biometry is commonly used in routine NHS standard practice as it is user-friendly, convenient, fast, does not require direct contact with the individual's eye and generates the results immediately. In addition, commonly used optical biometry machines have the capability of providing both axial length and keratometry measurements so additional corneal curvature measuring devices are not required. However, the committee noted that optical biometry is not appropriate in some individuals, for example, those with dense cataracts, and in those cases ultrasound biometry becomes necessary. The committee noted that in current UK practice, optical biometry machines may be used to measure keratometric readings, even in these situations where ultrasound biometry is required to measure axial lengths. In contrast, ultrasound biometry procedures are more complicated, requiring experienced technicians to minimise measurement errors resulting from for example, excessive corneal indentations that artificially shortens the length of the eye, or off-axis readings. Contact ultrasound biometry also requires an anaesthetic to be administered with a small risk of infection and abrasion, while immersion ultrasound biometry requires an eye water bath. However, the committee noted that ultrasound biometry is convenient as the machine is portable and therefore can be useful in tandem with hand-held keratometers for individuals with limited mobility or reduced ability to comply (for example, reduced cognitive function). The committee noted that owing to the limited availability of expertise in ultrasound biometry in the NHS, there may be delays in undertaking the assessment and obtaining the results, particularly if the individual has to be referred to another centre. The committee highlighted that ultrasound and optical biometry measure different points on the retina which must be considered when calculating the intraocular lens power. No statistically significant differences in absolute prediction errors were observed for ultrasound and optical biometry, irrespective of the type of ultrasound biometry (although the committee recognised that specific studies only comparing immersion and contact ultrasound biometry were excluded). The committee also noted that both ultrasound and optical biometry showed proportions of individuals exceeding the standard benchmarks for attaining a final spherical equivalent within 0.50 dioptres and 1.00 dioptre of the predicted refraction.

	The committee noted that automated keratometry is currently used in NHS standard practice to assess corneal curvature measurements in routine cataract surgery patients with regular corneas. However, keratometry may not be appropriate for some individuals. Therefore, corneal topography is a useful adjunct in patients with irregular corneas or a history of corneal refractive surgery. The committee also noted that corneal topography may be useful in circumstances where the cornea is abnormally flat (<41.00 dioptres) or steep (>47.00 dioptres) or if there is significant astigmatism (delta K >2.50 dioptres) to assist in planning of incision techniques. The committee agreed that there is a significant cost attached to the machinery for corneal topography, particularly in light of its relatively infrequent use in biometry. Moreover, a high level of skill is required to undertake corneal topography, the equipment may not be available in all ophthalmology departments and measurements take longer, requiring expertise in interpreting the data. The committee also noted that machines and techniques measure different points on the eye and use different readings.
Consideration of health benefits and resource use	For optical biometry, the main cost relates to the cost of the equipment, which is already *in situ* in NHS clinics. In addition, cost is offset by the volume of use and throughput, and the lower staff time and experience required. For ultrasound biometry, the main costs relate to higher staff time and experience required, because ultrasound biometry equipment is widely available in all departments. Access to ultrasound biometry-experienced technicians is rapidly declining as optical biometry becomes ubiquitous. The impact of this is resource limitation and the need to refer individuals to clinics that still have staff with the expertise to undertake ultrasound biometry. The committee noted that the evidence indicates that both ultrasound and optical biometry are effective. However, given the practical advantages of optical biometry, the most efficient way of implementation is as currently observed in standard NHS practice, where optical biometry is routinely used, and ultrasound biometry used in special circumstances. In spite of this, the committee agreed that it was important to maintain competence in ultrasound biometry within the NHS. The committee noted that the main costs attached to corneal topography is in the acquisition cost of the machine and the requirement for highly skilled and experienced staff to operate the equipment and interpret the results.
Quality of evidence	The committee noted that only 5 relevant randomised controlled trials were identified for the comparison on ultrasound vs. optical biometry. It noted that there was a larger body of evidence consisting of comparative case series that may provide further evidence for this comparison, but agreed that given the potential confounding factors of the observational studies, the best study design to consider the effectiveness of the different biometry techniques was the randomised controlled trial. The committee agreed that the overall quality of evidence was low because of the risk of bias associated with the limited reporting in the studies, and the lack of generalisability on the use of ultrasound biometry in the studies compared with standard NHS clinical practice. It noted that all studies used 1 experienced practitioner/technician to undertake all the ultrasound biometry measurements and therefore, inter-observer reliability would not be captured. It agreed that the accuracy and reliability of ultrasound biometry is heavily dependent on technicians' experience and therefore was not confident that the observed findings would be reproducible in current NHS clinical practice, where

ultrasound biometry is no longer routinely used, which has implications on staff training and expertise.

The committee discussed the evidence and noted that the randomisation methods used in Fontes et al. (2011) were unclear and that the 2 groups were of very different sizes, suggesting the possibility of biased allocation. The minimum age in the optical biometry group was reported to be 11 years and while it was likely to be different pathology (e.g. congenital cataracts), there was agreement that this would have little impact on this particular review question as the eye at that age is at a mature size. Moreover, it was noted that the overall mean age for the optical biometry group was 70 years with a small standard deviation, suggesting that it is likely to be 1 or 2 outliers, which should not considerably affect the results. The committee also noted that the study applied the Holladay I formula which is not considered optimal in current UK practice but agreed that since both biometry groups used the same formula, the overall findings should not be affected.

The committee discussed the issue of confounding with non-standardised keratometry, given that keratometric readings are also required in intraocular lens formulas. Rajan et al. (2002) did not undertake standardised keratometry and Fontes et al. (2011) did not report any details on keratometry measurements.

The committee noted the generally small studies (1 randomised controlled trial and 2 retrospective case series) that were identified for the comparison on keratometry vs. topography. It agreed that the evidence was very low quality. Specifically for the randomised controlled trial, it noted the high risk of bias from the lack of reporting of specific methods, large imprecision in the point estimates and the limited generalisability given that the study was published in 1995 such that clinical practice, keratometry and topography technology have progressed.

The committee discussed the evidence from the 2 retrospective studies that included the specific subgroup of individuals with a history of corneal refractive surgery undergoing phacoemulsification cataract surgery. The committee agreed that the evidence was very low quality noting its retrospective nature, and that practice may have changed over time. In addition, the committee agreed that mixed populations containing individuals with different types of refractive surgeries (e.g. laser-assisted in situ keratomileusis, photorefractive keratectomy, radial keratotomy) for varying indications (e.g. myopia, hyperopia) should not be pooled as different surgical techniques would impact upon measurements due to altered corneal shape and stability of keratometry (e.g. individuals with a history of radial keratotomy have diurnal fluctuations in corneal curvature measurements). Moreover, the indication of surgery would typically determine the appropriate intraocular lens formula that should be used. The committee also noted the variability in observed effect depending upon the type of topography machine, topography reading, formulas and point estimate used in the analysis. It agreed that it was difficult to determine the effectiveness of keratometry vs. topography given these confounding issues.

The committee also noted that there was variation between the studies in the intraocular lens formulas and constants that were used. However, because the techniques used were the same within each study (and therefore comparative data from a study are done using a consistent technique), the committee did not believe this was likely to be a source of considerable bias.

As a result of the particular poor quality evidence base on the optimal biometry techniques in people who have had previous corneal

	refractive surgery, the committee agreed it was appropriate to make a research recommendation for this group of patients.
Other considerations	The committee noted that there is no true gold standard for biometry (axial length) and keratometry (corneal curvature), but agreed that all instruments should be calibrated as per manufacturer's recommendations. The committee agreed that, in patients with a history of corneal refractive surgery, the specific machine used to measure corneal curvature is less relevant than choosing the most appropriate and effective method. Because of the wide range of methods offered to estimate the corneal power used to calculate intraocular lens power following corneal refractive surgery, it is general practice to use a consensus of several methods to obtain an average. The predictability of cataract outcome after corneal refractive surgery is less than that in previously untreated eye and the patients should be counselled accordingly preoperatively. The committee emphasised the importance of personalisation based on specific equipment and techniques used and other related issues such as, surgeon factors. The committee noted that as part of routine practice, both eyes are normally assessed in the same visit to validate biometry readings. It noted that although optical biometry readings are directly transferred by some instruments into intraocular lens calculation programmes, there is a possibility of transcription errors for both techniques depending on the operating protocols used in individual clinics.

7.1.7 Recommendations

8. Use optical biometry to measure the axial length of the eye for people having cataract surgery.

9. Use ultrasound biometry if optical biometry does not give accurate measurements.

10. Use keratometry to measure the curvature of the cornea for people having cataract surgery.

11. Consider corneal topography for people having cataract surgery:

- who have abnormally flat or steep corneas
- who have irregular corneas
- who have significant astigmatism
- who have had previous corneal refractive surgery **or**
- if it is not possible to get an accurate keratometry measurement.

7.1.8 Research recommendation

3. What is the effectiveness and cost effectiveness of biometry techniques in adults undergoing phacoemulsification cataract surgery with a history of corneal refractive surgery?

Why this is important

The number of individuals undergoing corneal refractive surgery is increasing, and a significant number of these individuals will eventually develop age-related cataracts. The corneal changes resulting from different types of refractive surgeries provide a challenge in undertaking accurate biometry assessments, and may result in worse visual outcomes of

surgery in this population compared with people without prior corneal refractive surgery. Robust evidence from randomised controlled trials is needed to inform the appropriate techniques that should be used in undertaking biometry including equipment, readings and formulas.

7.2 Intraocular lens formulas

7.2.1 Review question

- What are the most appropriate formulas to optimise intraocular lens biometry calculation?

7.2.2 Introduction

The evolution of theoretical intraocular lens (IOL) formulas, based on geometrical optics, is universally accepted as an essential factor contributing to the improvement of predictability of the refractive outcome with modern cataract surgery. Implicit to the third generation formulas is the variation of the effective lens position (ELP), previously referred to as anterior chamber depth (ACD), with corneal power and, in particular, the axial length of the patient's eye. Fourth generation formulas such as Olsen and Holladay II have further improved ELP accuracy by adding variables including lens thickness. Parallel with refinement of IOL formulas has been improvement of biometry measurements, particularly axial length, with devices employing infra-red laser interferometry such as the 'IOLMaster' and 'Lenstar'.

In 2001, the Royal College of Ophthalmologists published cataract surgery guidelines recommending the most appropriate IOL formulas, available at that time, for given axial length. Although these guidelines were widely acknowledged, the National Biometry audit demonstrated lack of awareness of and poor compliance with these recommendations, and also emphasised the importance of customising A constants (a measure of lens power) to minimise prediction error.

Increasingly, patients undergoing cataract surgery are likely to have a history of corneal refractive laser surgery such as laser-assisted in situ keratomileusis (LASIK) and laser-assisted sub-epithelial keratomileusis (LASEK). This is important because such surgeries alter the relationship between the anterior and posterior corneal curvature and thereby renders inaccurate the basic assumptions regarding the power of the central cornea in IOL formulas. As a result, there is a risk of unpredictable under correction of the corneal power which will result in the eye being hyperopic after cataract surgery.

The aim of this review was to determine the most appropriate IOL formulas that should be used in different circumstances in order to optimise intraocular lens calculation. The Guideline committee prioritised the following circumstances:

- 'Virgin' eyes without a history of corneal refractive surgery within various ranges of axial lengths, categorised (RCO, 2010) into:
  - *Short*: less than 22.00mm
  - *Average length*: 22.00 to 24.50mm
  - *Medium long*: 24.50 to 26.00mm
  - *Very long*: more than 26.00mm
- People with a history of corneal refractive surgery, categorised into:
  - *Refractive error*: myopia vs. hypermetropia
  - *Surgical procedure*: laser-assisted in situ keratomileusis (LASIK), laser-assisted sub-epithelial keratomileusis (LASEK), photorefractive keratectomy (PRK) vs. radial keratotomy (RK)

The review focused on identifying studies that fulfilled the conditions specified in Table 13. For full details of the review protocol, see Appendix C. The main outcome for this review question was the predictive accuracy of the different IOL formulas, assessed by deviations from the predicted refractive outcome expressed as a spherical equivalent. As suggested by Gale et al. (2009), a benchmark standard of 85% of individuals achieving a final spherical

equivalent within 1.00 dioptre of the predicted refraction and 55% of individuals within 0.50 dioptres was used to evaluate the clinical relevance of the review findings.

Table 13: PICO inclusion criteria for the review question on intraocular lens formulas

Population	Adults (18 years and over) undergoing biometry prior to phacoemulsification cataract surgery with intraocular lens implantation
Interventions	**Formulas used in intraocular lens biometry calculations** Examples: Haigis, Hoffer Q, Holladay 2, Sanders/Retzlaff/Kraff (SRK/T), Barrett Universal II, Olsen **Excluded:** Binkhorst II, Holladay 1, SRK I, SRK II
Comparators	All formulas vs. each other
Outcomes	• Deviation from predicted refractive outcome expressed as a spherical equivalent • Resource use and cost

No relevant randomised controlled trials (RCTs) comparing different IOL formulas in adults undergoing phacoemulsification cataract surgery to predict the accuracy of postoperative refraction were identified. Papers were excluded if they:

- were guidelines/health technology assessment reports, narrative reviews, case studies/reports/series, reliability studies, diagnostic accuracy studies, non-comparative studies
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- focused on combination surgical procedures – that is, cataract surgery in tandem with other surgical procedures (for example, phacotrabeculectomy, canaloplasty, Descemet's stripping automated endothelial keratoplasty)
- did not provide adequate information to assess the status of ocular comorbidities or previous ocular surgeries
- did not provide separate subgroup data of axial lengths in virgin eyes
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

Protocol deviation

Given that no relevant RCTs were identified, the search was expanded to include comparative observational studies. Eighteen relevant observational studies that compared the predictive accuracy of different IOL formulas in a range of axial lengths of virgin eyes undergoing phacoemulsification cataract surgery were identified. Six observational studies in eyes with a history of corneal refractive surgery were included. Since these studies were in the form of intra-person comparisons (where every tested formula was calculated for each individual in the study), it was agreed the usual concerns associated with using non-randomised data were not relevant here, and therefore observational studies were started as being high-quality evidence in the GRADE framework, and downgraded from that point.

7.2.3 Evidence review

In total, 18,080 references were found for a combined database search for all 4 related review questions on biometry and postoperative refractive errors, with 315 articles ordered for full-text review. Fourteen observational studies on virgin eyes undergoing phacoemulsification cataract surgery were included (Aristodemou et al., 2011; Bang et al., 2011; Carifi et al., 2015; Day et al., 2012; El-Nafees et al., 2010; Eom et al., 2014; Mitra et al., 2014; Moschos et al., 2014; Percival et al., 2002; Petermeier et al., 2009; Srivannaboon et al., 2013; Tsang et al., 2003; Wang and Chang, 2013; Wang et al., 2011). Six comparative

observational studies on eyes with a history of corneal refractive surgery undergoing subsequent phacoemulsification cataract operations were included. All studies included people with myopic LASIK/LASEK or PRK (Fam and Lim, 2008; Huang et al., 2013; Kim et al., 2013; Saiki et al., 2013; Savini et al., 2010; Xu et al., 2014). The formulas used for eyes with prior corneal refractive surgery were categorised as historical data methods (where information on patient history is used as part of the calculation) and no historical data methods (where patient history is not used as part of the calculation).

At the update searches, 13 full text articles were evaluated and 4 comparative case series on virgin eyes undergoing phacoemulsification cataract surgery were included (Cooke and Cooke, 2016; Doshi et al., 2017; Kane et al., 2016; Ozcura et al., 2016).

7.2.3.1 Description of included studies

Details of the included studies are found in the evidence tables (see Appendix E).

7.2.3.1.1 Virgin eyes without a history of corneal refractive surgery

Of the 18 identified studies, 17 provided usable data (exception Tsang et al., 2003). All studies were comparative case series, 15 retrospective and 3 prospective (Doshi et al., 2017; El-Nafees et al., 2010; Srivannaboon et al., 2013). All studies with the exception of Petermeier et al. (2009) stated that the phacoemulsification cataract surgery was uneventful or people with intraoperative/postoperative complications had been excluded. Table 14 provides a summary of the key study characteristics.

7.2.3.1.2 People with a history of corneal refractive surgery

All studies were comparative case series, 5 retrospective and 1 prospective (Huang et al., 2013) including eyes with a history of myopic LASIK/LASEK/PRK. All studies with the exception of Fam and Lim (2008) stated that the phacoemulsification cataract surgery was uneventful. Table 14 provides a summary of the key study characteristics.

1799 **Table 14: Summary of key characteristics of included studies for virgin eyes without a history of corneal refractive surgery**

Study & location	Population	Preoperative biometry	Types of intraocular lens	Axial length subgroup
Aristodemou 2011 England	8,108 eyes Postoperative corrected distance visual acuity (CDVA) of at least 6/12 Excluded: corneal astigmatism >3.00D, concurrent additional surgical procedures	IOLMaster IOL constant optimised	Separate results reported: ○ Sofport Advanced Optics L161AO ○ Akreos Fit	<22.00mm 22.00-24.50mm 24.50-26.00mm >26.00mm
Bang 2011 USA	53 eyes Postoperative CDVA of at least 20/40 Excluded: history of amblyopia, severe macular damage	IOLMaster IOL constant optimisation not reported	Combined results reported: ○ MA60MA ○ MA50BM ○ SA60AT	>26.00mm
Carifi 2015 England	28 eyes Excluded: combined surgical procedures, previous intraocular surgery, intraoperative complications, any corneal pathology, marked lens opacities, postoperative CDVA worse than 20/40	IOLMaster IOL constant optimised (ULIB)	SA60AT	<22.00mm
Cooke 2016 USA	1079 eyes Postoperative CDVA of at least 20/25 Excluded: additional ocular surgery, history of contact lens wear, intraoperative complications, ocular or systemic disease that might have prevented obtaining good preoperative measurements, unexpected refractions, second eye surgery	IOLMaster Lenstar IOL constant optimised	Acrysof SN60WF	≤22.00mm ≥26.00mm
Day 2012 England	163 eyes Excluded: previous corneal refractive surgery	IOLMaster Data available for IOL constant optimised and not optimised	Separate and combined results reported: ○ Akreos AO ○ Akreos Adapt ○ Corneal ACR6D ○ Oculentis Lentis L302-1	<22.00mm
Doshi 2017 India	80 eyes Postoperative best corrected visual acuity (BCVA) of 6/12 or better Excluded: people with psychiatric illness, traumatic cataract, several corneal degeneration, corneal	Immersion ultrasound and IOLMaster IOL constant optimised	Not reported	<22.00mm >24.50mm

Study & location	Population	Preoperative biometry	Types of intraocular lens	Axial length subgroup
	opacity, vitreous degeneration and other vitreous pathology, diabetic retinopathy, developmental and acquired retinal diseases, squint and high corneal astigmatism			
El-Nafees 2010 Egypt	53 eyes Excluded: previous ocular surgery, combined surgical procedures, eventful cataract surgeries, corneal surface irregularities	Ultrasound biometry IOL constant optimisation not reported	I-Medical	25.50-31.40mm
Eom 2014 South Korea	75 eyes Excluded: history of traumatic cataracts, previous ocular surgery, complicated cataract surgery, sulcus-fixated lenses, postoperative complications	IOLMaster IOL constant optimised	Acrysof IQ	<22.00mm
Kane 2016 Australia	3241 eyes Postoperative CDVA better than 6/12 Excluded: corneal astigmatism >3.00D, complicated cataract surgery, additional procedures during cataract surgery, postoperative complications	IOLMaster IOL constant optimised	Acrysof IQ SN60WF	<22.00mm 22.00-24.50mm 24.50-26.00mm >26.00mm
Mitra 2014 India	43 eyes Excluded: pre-existing astigmatism >3.00D, corneal scar, keratoconus, complications affecting refractive status	Ultrasound biometry IOL constant optimisation not reported	Not reported	24.50-26.50mm
Moschos 2014 Greece	69 eyes Postoperative best corrected visual acuity (BCVA) of 20/40 or better Excluded: preoperative BVCA of 20/200 or worse, corneal abnormalities, previous intraocular or corneal surgery, history of ocular injury or uveitis	Ultrasound biometry IOL constant optimised	SN60WF	<22.00mm
Ozcura 2016 Turkey	485 eyes Postoperative visual acuity of 20/40 or better Excluded: combined procedures, postoperative astigmatism >2.00D	Ultrasound biometry IOL constant optimisation not reported	Not reported	≤22.00mm 22.00-25.00mm ≥25.00mm
Percival 2002 England	500 eyes Excluded: surgical complications preventing in-the-bag implantation, corneal pathology, extreme dementia	Ultrasound biometry IOL constant optimised	Centerflex	<22.00mm 22.00-24.50mm 24.50-26.00mm >26.00mm

Study & location	Population	Preoperative biometry	Types of intraocular lens	Axial length subgroup
Petermeier 2009 Germany	50 eyes Excluded: pathology affecting accuracy of biometry (for example, retinal detachment, corneal scars), severely reduced visual acuity (hand movements or worse), unable to participate in refraction because of glaucoma, amblyopia or myopic degeneration	IOLMaster Data available for IOL constant optimised and not optimised	Separate results reported for MA60MA based on ○ positive dioptre ○ negative dioptre ○ zero dioptre	>26.00mm
Srivannaboon 2013 Thailand	163 eyes Excluded: other ocular diseases, previous ocular surgery	IOLMaster and ultrasound biometry IOL constant optimised (ULIB)	Hoya PY60AD	<22.00mm 22.00-24.50mm >24.50mm
Wang 2013 Taiwan	200 eyes Excluded: ocular pathology, operative complications	IOLMaster IOL constant optimised	SA60AT	<22.00mm 22.00-26.00mm >26.00mm
Wang 2011 USA	106 eyes Postoperative CDVA of 20/30 or better Excluded: previous ocular surgery, intraoperative or postoperative complications	IOLMaster Axial length optimised	IOLs combined in the following groups: ○ MA60MA/MA60AC ○ SA60AT/SN60AT/SN60T ○ SN60WF	25.01-30.78mm

1800

1801 **Table 15: Summary of key characteristics of included studies for eyes with a history of myopic LASIK/LASEK/PRK**

Study & location	Population	Biometry/Types of intraocular lens	Postoperative assessment	Formulas/methods
Fam 2008 Singapore/Malaysia 6 centres/number of surgeons not reported	37 eyes Myopic LASIK or PRK Mean AL: 26.63mm	Biometry: not reported IOL constant optimisation: implanted IOL A-constant IOL: not reported	1 month	Historical data methods: SRKT Clinical history, Hoffer Q DK, Holladay 2 DK, SRKT DK, SRKT Feiz-Mannis, SRKT Ladas-Stark
Huang 2013 USA 2 centres/5 surgeons	46 eyes Myopic LASIK, LASEK or PRK Mean AL: not reported	Biometry: IOLMaster IOL constant optimisation: personalised Haigis constants for Haigis-L only IOL: Alcon SN60AT, SA60AT, SN60WF, SN6AT3/4; AMO ZA9003, ZCB00	Manifest refraction: 1 month	No historical data methods: Haigis-L, Shammas-PL
Kim 2013 South Korea 1 centre/1 surgeon	47 eyes Myopic LASIK or PRK Mean AL: 27.75mm	Biometry: IOLMaster, immersion ultrasound IOL constant optimisation: not reported IOL: Alcon SN60AT	Manifest refraction: 2 months	No historical data methods: Haigis-L, SRKT K
Saiki 2013 Japan Number of centres or surgeons not reported	28 eyes Myopic LASIK Mean AL: 26.19mm	Biometry: IOLMaster (AL and ACD), UD-6000 ultrasound scanner (ACD) Keratometry: IOLMaster, ARK10000, Scheimpflug, ARK-730A autokeratometer, Pentacam IOL constant optimisation: ULIB optimised lens constants IOL: not reported	Manifest refraction: 1 month	No historical data methods: SRKT TNP, SRKT A-P, BESSt, SRKT C-P, SRKT DK, Camellin-Calossi, Haigis-L, Shammas-PL Historical data methods: Double-K, Feiz-Mannis, Masket, Modified Masket
Savini 2010 Italy Number of centres not reported/12 surgeons	28 eyes Myopic LASIK or PRK Mean AL: 27.84mm	Topography: TMS-2, Keratron, CM02, EyeSys System 3000 (simulated K used) IOL constant optimisation: implanted IOL A-constant, not optimised IOL: not reported	Spherical equivalent: 1 month	No historical data methods: Shammas-PL Historical data methods: Clinical history, SRKT DK Awwad, Camellin-Calossi, SRKT Diehl, SRKT DK, SRKT Feiz-Mannis, SKRT Feiz-Mannis nomogram, SRKT SK Ferrara, SRKT Ladas-Stark, SRKT Latkany, SRKT Masket, SRKT SK Rosa, SRKT DK Savini, SRKT DK Seitz/Speicher, SRKT DK Seitz/Speicher/Savini, SRKT DK Shammas

Study & location	Population	Biometry/Types of intraocular lens	Postoperative assessment	Formulas/methods
Xu 2014 China Number of centres not reported/1 surgeon	37 eyes Myopic LASIK, LASEK or PRK Mean AL: 29.52mm	Biometry: immersion ultrasound A-scan (AL) Topography: Pentacam Scheimpflug IOL constant optimisation: not reported IOL: not reported	12 weeks	No historical data methods: SRKT K, SRKT TNP, Hoffer Q K, Hoffer Q TNP

[AL]axial length, [IOL]intraocular lens, [LASEK]laser-assisted sub-epithelial keratomileusis, [LASIK]laser-assisted in situ keratomileusis, [PRK]photorefractive keratectomy, [DK]double-K, [SK]single K, [K]simulated K (IOLMaster), [TNP]true net power

1802

1803

7.2.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which none were retained for this review question. Health economic modelling was not prioritised for this review question.

7.2.5 Evidence statements

7.2.5.1 Virgin eyes without a history of corneal refractive surgery

7.2.5.1.1 Axial lengths less than 22.00mm

Evidence from 5 network meta-analyses and 1 pairwise comparison including data from up to 11 case series showed that the SRK/T formula had the lowest predictive accuracy for intraocular lens power calculations as assessed by mean absolute error and proportion of people achieving predicted target within 0.25, 0.50, 1.00 and 2.00 dioptres. Haigis and Hoffer Q formulas showed the highest predictive accuracy with lowest imprecision as assessed by mean absolute error and proportion of people achieving predicted target within 0.25, 0.50 and 2.00 dioptres. The overall quality was assessed to be very low to moderate (see Appendix G for the GRADE tables and Appendix H for the results of the network meta-analyses).

7.2.5.1.2 Axial lengths 22.00-24.50mm

Evidence from 5 network meta-analyses including data from up to 4 case series showed that the Barrett Universal II and SRK/T formulas were similarly effective in terms of predictive accuracy of intraocular lens power calculations as assessed by mean absolute error and proportion of people achieving predicted target within 0.25, 0.50, 1.00 and 2.00 dioptres. The overall quality was assessed to be moderate to high (see Appendix G for the GRADE tables and Appendix H for the results of the network meta-analyses).

7.2.5.1.3 Axial lengths 24.50-26.00mm

Evidence from 5 network meta-analyses including data from up to 6 case series showed that the Barrett Universal II formula was most effective in terms of predictive accuracy of intraocular lens power calculations as assessed by the proportion of people achieving predicted target within 0.25, 0.50, 1.00 and 2.00 dioptres. SRK/T formula was effective in terms of predictive accuracy of intraocular lens power calculations as assessed by the proportion of people achieving predicted target within 2.00 dioptres. The overall quality was assessed to be low to moderate. The overall quality was assessed to be very low to high (see Appendix G for the GRADE tables and Appendix H for the results of the network meta-analyses).

7.2.5.1.4 Axial lengths greater than 26.00mm

Evidence from 5 network meta-analyses and 1 pairwise comparison including data from up to 8 case series showed that the SRK/T and Haigis formulas had the highest predictive accuracy for intraocular lens power calculations as assessed by the proportion of people achieving predicted target within 0.25, 0.50 and 2.00 dioptres. The overall quality was assessed to be low to moderate (see Appendix G for the GRADE tables and Appendix H for the results of the network meta-analyses).

7.2.5.2 Eyes with a history of myopic LASIK/LASEK/PRK

7.2.5.2.1 Historical and no historical data methods

Evidence from 5 network meta-analyses and 1 pairwise comparison including data from up to 5 case series showed that it was not possible to distinguish between the formulas tested, as assessed by mean absolute error, mean prediction error, or the proportions of people achieving predicted target within 0.50 and 1.00 dioptres. The Haigis-L formula was more effective than the SRK/T formula, as assessed by the proportions of people achieving predicted target within 1.50 and 2.00 dioptres. The overall quality was assessed to be very low to low (see Appendix G for the GRADE tables and Appendix H for the results of the network meta-analyses).

7.2.5.2.2 No historical data methods

Evidence from 4 network meta-analyses including data from 4 case series showed that it was not possible to distinguish between the formulas tested, as assessed by the proportions of people achieving predicted target within 0.50 and 1.00 dioptres. The overall quality was assessed to be very low (see Appendix G for the GRADE tables and Appendix H for the results of the network meta-analyses).

7.2.5.2.3 Historical data methods

Data from 2 network meta-analyses and 1 pairwise comparison including data from up to 2 case series showed that it was not possible to distinguish between the formulas tested, as assessed by mean absolute error or the proportion of people achieving predicted target within 2.00 dioptres. The SRK/T formula had the lowest predictive accuracy, as assessed by the proportion of people achieving predicted target within 0.50 and 1.00 dioptres. The overall quality was assessed to be very low (see Appendix G for the GRADE tables and Appendix H for the results of the network meta-analyses).

7.2.5.3 Health Economic Evidence

No health economic evidence was identified for this review question.

7.2.6 Evidence to recommendation

Relative value of different outcomes	The Guideline committee agreed that the critical outcome for decision-making was deviation from predicted refractive outcome, though resource use and costs were also considered to be important. The committee agreed that, of the different refractive outcomes presented, the proportion of people with 0.5 dioptres was likely to be the most relevant, as this was the clinically relevant outcome for which the largest amount of data was available (smaller errors are unlikely to have a meaningful impact on patients' vision; larger ones are uncommon events regardless of formula). The committee highlighted the importance of selecting appropriate intraocular lens (IOL) formulas depending on the axial length of the eye and in specific circumstances where a history of corneal refractive surgery are likely to impact upon the shape of the cornea, such that resulting keratometry and/or topography measurements would require adjustments when applied to standard formulas.
Trade-off between benefits and harms	The committee agreed that the SRK/T formula was the most appropriate to use as the reference category in the analyses (where it was available), as it was the formula used most commonly across the different trials and outcome measures, and is one that is in use in clinical practice. The committee noted that individual IOL formulas used a range of variables in addition to IOL constants, with the simplest including only

2 measurements, that is, axial length and keratometric reading (for example, Hoffer Q, SRK/T), while others included 7 variables (for example, Holladay 2 uses axial length, keratometry, preoperative anterior chamber depth and refraction, lens thickness, age and horizontal white-to-white measurement). However, the committee agreed that these formulas were comparable when considered as complex interventions and noted that all required measurements including those for the Holladay 2 (with the exception of lens thickness) can be obtained using standard modern biometry machines. The committee noted the recently published Super Formula which uses other formulas (Haigis, Hoffer Q, Holladay 1 with and without Wang-Koch adjustment).

The committee noted the general high levels of statistical imprecision observed across all the formulas and outcomes. For eyes without a history of corneal refractive surgery, the main results of the evidence synthesis were that the SRK/T formula performs poorly in eyes with short axial lengths (those less than 22.00mm) in contrast to eyes with very long axial lengths (those greater than 26.00mm), and the Hoffer Q performs poorly in eyes with very long axial length (greater than 26.00mm). The Haigis formula was among the best options for 3 of the 4 axial length subgroups.

Eyes with short axial lengths

For eyes with short axial lengths, the Hoffer Q formula was similarly effective to the Haigis in predictive accuracy. Barrett Universal II and SRK/T formulas were the best options for eyes with average or medium long axial lengths. While several newer formulas showed trends towards better predictability, the committee was hesitant to recommend these formulas because of the high levels of statistical imprecision and small study samples. Therefore, they agreed it would be more appropriate to make a research recommendation looking at the effectiveness of these newer formulas in larger studies.

The committee noted that, for eyes with a history of corneal refractive surgery, the absolute levels of prediction error were worse than in eyes without previous surgery. For example, across all studies and formulas, in the non-surgery group, for axial lengths between 22.00 and 24.50mm, 70.1% of the prediction errors were less than 0.50 dioptres, while in eyes with prior surgery, only 31.1% of the prediction errors were less than 0.50 dioptres. The committee therefore agreed it was appropriate to make a research recommendation looking at the most appropriate formulas to use in people with prior corneal refractive surgery.

Eyes with a history of corneal refractive surgery

For eyes with a history of corneal refractive surgery, it was not possible to identify formulas that provided consistently better results than others, as there was considerable uncertainty and heterogeneity in the evidence base. The formulas used across multiple studies produced very different levels of accuracy in different studies, and the committee was not able to identify aspects of the study design or patient population that would adequately explain these levels of heterogeneity. The committee noted, however, that there was a pattern of formulas which did make adjustments performing better than those based on clinical history alone, implying that making an adjustment is better than not doing so, even if it was not possible to recommend which particular adjustment should be made. The committee also agreed that, given the clear evidence that predictions were less accurate in this group, this information should be communicated to patients before surgery, to ensure they are fully informed and have realistic expectations of the benefits they are likely to receive from surgery.

Consideration of health benefits and resource use	No health economic evidence was found for this review question, and it was not prioritised for *de novo* modelling work. However, the committee noted that various IOL formulas are available as a standard package within more recent biometry machines (which the committee confirmed were widely in use), but some of the newer formulas may require additional proprietary licenses, although this does not apply to those formulas which are recommended here. The committee did not consider the recommendations made would have significant resource implications.
Quality of evidence	The committee noted the lack of randomised controlled trials examining the effectiveness of different IOL formulas. The committee agreed that it may have been useful to consider narrower ranges of axial lengths in order to identify critical thresholds for the appropriate use of different IOL formulas. However, the committee noted that only 1 large UK-based study provided this level of detailed evidence (Aristodemou et al. 2011) for the Hoffer Q and SRK/T formulas, and that the reported findings for axial length subgroups in increments of 0.5 to 1.0mm were congruent with the overall network meta-analysis results observed for the 4 prioritised axial length classes. The committee also highlighted that focusing on narrower bands of axial lengths would impact upon the statistical power and precision of the findings. The committee agreed that strict selection criteria excluding studies that did not specify phacoemulsification cataract surgery or did not provide adequate information to assess the status of ocular comorbidities or previous ocular surgeries and/or separate subgroup data of axial lengths in virgin eyes were necessary to ensure that the included studies were adequately homogeneous to be included in a network meta-analysis. However, the committee recognised that this meant 2 specific papers that have been relied on in other guidelines were excluded (MacLaren et al. 2007 and Narvaez et al. 2006). The committee noted that the sensitivity analyses based on the type of biometry undertaken and the use of IOL constant optimisation also showed little variation compared with the overall findings of all included studies. The committee agreed that the overall quality of evidence was very low to moderate, and noted that the evidence for people with prior corneal refractive surgery was of particularly low quality, consisting mainly of small retrospective studies (and with no evidence at all in eyes post radial keratotomy). The committee also noted that the formulas assessed in the included papers had all been derived from retrospective analyses, and none had been subject to prospective testing. The committee noted that, in some analyses, the ordering of effectiveness of the interventions differed between the analyses looking at mean absolute error and those looking at the proportion of people within 0.5D. They agreed this was likely to be because the mean difference results were being skewed by a small proportion of people having very large errors in prediction. The committee agreed the within 0.5D evidence was more appropriate for decision making, as once an error reaches a certain level the clinical outcome (of lens explantation and new lens insertion) is the same, regardless of the magnitude of the error.
Other considerations	The committee agreed that, given the lack of distinction in predictive accuracy of different IOL formulas for axial lengths ranging from 22.00 to 24.50mm and 24.50 to 26.00mm, it would be useful to group these bandings in the recommendations.

7.2.7 Recommendations

12. **For people who have not had previous corneal refractive surgery, use one of the following to calculate the intraocular lens power before cataract surgery:**
    - If the axial length is less than 22.00 mm, use Haigis or Hoffer Q.
    - If the axial length is between 22.00 and 26.00 mm, use Barrett Universal II if it is installed on the biometry device and does not need the results to be transcribed by hand. Use SRK/T if not.
    - If the axial length is more than 26.00 mm, use Haigis or SRK/T.

13. **Advise people who have had previous corneal refractive surgery that refractive outcomes after cataract surgery are difficult to predict, and that they may need further surgery if they do not want to wear spectacles for distance vision.**

14. **If people have had previous corneal refractive surgery, adjust for the altered relationship between the anterior and posterior corneal curvature. Do not use standard biometry techniques or historical data alone.**

7.2.8 Research recommendations

4. **How effective are newer intraocular lens formulas (for example, Barrett, Olsen, T2) compared with standard formulas for phacoemulsification cataract operations on eyes without a history of corneal refractive surgery, especially for long and short axial lengths?**

Why this is important

Appropriately applied intraocular lens (IOL) formulas are paramount to improving predictive accuracy and patient satisfaction following cataract surgery and IOL implantation. Despite significant technological advancement in ophthalmology, it is widely recognised that many of the currently used IOL formulas were developed more than 20 years ago. Newer formulas are being published but there is a dearth of evidence comparing their effectiveness to standard formulas in people without a history of corneal refractive surgery. Methodologically robust randomised controlled trials are needed to address this research gap.

5. **What is the effectiveness of different intraocular lens formulas for eyes after prior corneal refractive surgery, as measured in a prospectively collected multi-centre study?**

Why this is important

Appropriately applied intraocular lens (IOL) formulas are paramount to improving predictive accuracy and patient satisfaction following cataract surgery and IOL implantation. There are particular challenges in accurate prediction in people with a history of corneal refractive surgery, and there is a lack of evidence for the most effective formulas to use in this group, with a total absence of large, prospective studies. Methodologically robust randomised controlled trials are needed to address this research gap.

7.3 Intraocular lens constant optimisation

7.3.1 Review question

- What is the effectiveness of strategies used to select intraocular lens constants in order to optimise biometry calculation?

7.3.2 Introduction

The aim of this review was to determine the effectiveness of strategies used to select intraocular lens (IOL) constants in order to optimise biometry calculation.

The review focused on identifying studies that fulfilled the conditions specified in Table 16. For full details of the review protocol, see Appendix C. The main outcome for this review question was the predictive accuracy of the different optimisation strategies, assessed by deviations from the predicted refractive outcome expressed as a spherical equivalent. As suggested by Gale et al. (2009), a benchmark standard of 85% of individuals achieving a final spherical equivalent within 1.00 dioptre of the predicted refraction and 55% of individuals within 0.50 dioptres was used to evaluate the clinical relevance of the review findings.

Table 16: PICO inclusion criteria for the review question on intraocular lens constant optimisation

Population	Adults (18 years and over) undergoing biometry prior to phacoemulsification cataract surgery with intraocular lens implantation
Interventions and comparators	**Different optimisation methods of intraocular lens constants vs. each other** Examples: surgeon-specific lens constants, axial length-specific lens constants, keratometry-specific lens constants
Outcomes	• Deviation from predicted refractive outcome expressed as a spherical equivalent • Resource use and cost

No randomised controlled trials (RCTs) comparing different strategies to optimise IOL constants in adults undergoing phacoemulsification cataract surgery to predict postoperative refraction were identified. Papers were excluded if they:

- were guidelines/health technology assessment reports, narrative reviews, case studies/reports/series, reliability studies, diagnostic accuracy studies, non-comparative studies
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- focused on combination surgical procedures that is, cataract surgery in tandem with other surgical procedures (for example, phacotrabeculectomy, canaloplasty, Descemet's stripping automated endothelial keratoplasty)
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

Protocol deviation

Given that no relevant RCTs were identified, the search was expanded to include comparative observational studies. Nine relevant retrospective comparative case series that compared the predictive accuracy of different IOL constant optimisation strategies in virgin eyes without a history of corneal refractive surgery undergoing phacoemulsification cataract operations were identified. Since these studies were in the form of intra-person comparisons (where both optimisation and non-optimisation were considered for each individual in the

study), it was agreed the usual concerns associated with using non-randomised data were not relevant here, and therefore observational studies were started as being high-quality evidence in the GRADE framework, and downgraded from that point.

7.3.3 Evidence review

In total, 18,080 references were found for a combined database search for all 4 related review questions on biometry and postoperative refractive errors, with 315 articles ordered for full-text review. Nine observational studies on virgin eyes undergoing phacoemulsification cataract surgery were included (Aristodemou et al., 2011; Charalampidou et al., 2010; Day et al., 2012; Eom et al., 2013; Fam et al., 2009; Lee et al., 2015; Petermeier et al., 2009; Sharma et al., 2014; Wang et al., 2011).

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

7.3.3.1 Description of included studies

All 9 identified studies were retrospective comparative case series with sample sizes ranging from 50 to 8,108 eyes. With the exception of Petermeier et al. (2009), all studies stated that the phacoemulsification cataract surgery was uneventful or those with intraoperative/ postoperative complications had been excluded. All studies used optical biometry to undertake preoperative assessments (IOLMaster in 8 studies and Lenstar in Lee et al. 2015). One study (Aristodemou et al., 2011) tailored the use of IOL formula based on the individual eye's axial length. An extensive range of IOL constant optimisation methods was examined including the use of User Group for Laser Interference Biometry (ULIB) website to download IOL constants or personalise constants, back-calculating to achieve a prediction error of zero, using optimised axial length and/or keratometry readings, using IOL constants derived from biometry machines (IOLMaster, Lenstar), use of manufacturers' IOL constants, traditional A constants and optimising the axial length compared with using the IOLMaster axial lengths. Further details of the reported methods for optimisation are found in the evidence tables (see Appendix E).

7.3.3.2 Evidence review strategy

Separate data for excluded IOL formulas (that is, Binkhorst II, Holladay 1, SRK I and SRK II) reported in studies were not extracted or analysed. Where a study included multiple IOLs and reported both separate data for each IOL and combined data, the individually reported IOL data were preferentially used. Where a study reported results for multiple IOL formulas, the IOL formula that is recommended for the mean axial length of that study was preferentially extracted and analysed (see section 7.2 on intraocular lens formulas). Where a study reported several versions of the optimisation method, for example, using the entire sample to calculate individualised IOL constants vs. using half the sample and extrapolating to the full population; or the use of 3 optimised constants vs. 2, the option that would more likely provide the optimal optimisation was preferentially selected, that is, total sample individualised and 3 optimised constants.

7.3.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which none were retained for this review question. Health economic modelling was not prioritised for this review question.

7.3.5 Evidence statements

Evidence from 5 network meta-analyses and 1 pairwise comparison including data from up to 7 retrospective case series suggested that the use of standard IOL constants may be suboptimal in maximising the predictive accuracy of intraocular lens power calculations as assessed by mean absolute error and proportion of people achieving predicted target within 0.25, 0.50, 1.00 and 1.50 dioptres. The proportions of individuals achieving postoperative refraction within 0.50 and 1.00 dioptres were lower in groups using standard IOL constants (46.3% and 83%) compared with optimised constants (75.2% and 94.1%) in 5 and 6 low-quality retrospective case series (8,698 and 8,749 eyes) respectively. The overall quality was assessed to be low (see Appendix G for the GRADE table and Appendix H for the results of the network meta-analyses).

Evidence from 5 network meta-analyses and 1 pairwise comparison including data from up to 7 retrospective case series showed that, of the 7 different IOL constant optimisation methods assessed, none were significantly better than each other in improving predictive accuracy of intraocular lens power calculations. Two methods, surgeon's personalisation using the Users Group for Laser Interference Biometry (ULIB) framework and optimising individual IOL constants by back-calculating the prediction error to zero showed trends of being effective in improving the proportion of eyes achieving the predicted target within 1.00 and 0.25 dioptres respectively. The overall quality was assessed to be low (see Appendix G for the GRADE table and Appendix H for the results of the network meta-analyses).

7.3.5.1 Health Economic Evidence

No health economic evidence was identified for this review question.

7.3.6 Evidence to recommendations

Relative value of different outcomes	The Guideline committee agreed that the critical outcome for decision making was deviation from predicted refractive outcome, while resource use and costs were considered to be important. The committee noted that intraocular lens (IOL) constant optimisation was one of several strategies to improve postoperative refractive outcomes, involving adjustments specific to the IOL and individual surgeons. They highlighted that IOL manufacturers' tolerance for lens accuracy is variable and can range from 0.25 to 0.40 dioptres tolerance. Surgeon variables include the size and method of insertions such that small variations can result in systematic differences in postoperative refractive outcomes. The committee emphasised the importance of personalisation based on specific biometry equipment and techniques used, multiple preoperative assessment staff and other related issues such as surgeon factors.
Trade-off between benefits and harms	The committee noted that, historically, it was difficult to obtain audit data of prediction errors that can be used to inform IOL constant optimisation, as there were no robust mechanisms for returning postoperative outcome data, particularly where patients were discharged for postoperative refraction by community optometrists. However, such data are currently much more accessible with the availability of automated biometry with electronic storage of results. The committee agreed that the time taken to submit audit information is not overly onerous and therefore it would be useful to encourage departments to undertake such practice, to facilitate quality data sets that can be used to improve the accuracy of IOL constant optimisation. The committee recognised that this practice would need to be maintained as IOLs change over time. The committee noted that, generally, UK surgeons and departments do not formally calculate optimised constants, but rather use informal processes, for example, surgical teams apply adjustments (over- or

	under-estimates) based on reflection of their experience, type of IOL used (for example, standard vs. multifocal) and patient preference (for example, to be over- rather than under-corrected). The committee agreed that, overall, the evidence synthesis was suggestive that, compared with standard IOL constants, optimisation of IOL constants is likely to improve the predictive accuracy of postoperative refractive outcomes. However, this finding was subject to substantial statistical uncertainty: although there was a trend towards improved accuracy in all outcomes, credible intervals from the network meta-analyses tended to be very wide and only 1 comparison produced results that satisfied conventional definitions of statistical significance (adjusting the prediction error to zero for the proportion of eyes within 0.25 dioptres of the predicted postoperative refraction). The committee understood that this uncertainty was substantially caused by statistical heterogeneity in the underlying evidence, leading to large random-effects terms in the synthesis models. In particular, it was notable that the 2 trials that examined comparable strategies for calibrating prediction error to zero (Aristodemou et al., 2011 and Day et al., 2012) gave incongruent results, with substantial and significant accuracy gains in Aristodemou et al. (2011) but not in Day et al. (2012). The committee discussed that this discrepancy may have arisen because Day et al. (2012) was a small study restricted to eyes with short axial lengths (less than 22.00mm), whereas Aristodemou et al. (2011) was a much larger study including eyes of all sizes. The effect of this discrepancy was to 'dilute' the strongly significant gains demonstrated in the larger, more representative study, as the synthesis models had to estimate a broad, uncertain distribution of effects in order to fit the heterogeneous data. The committee therefore concluded that Day et al. (2012) had a disproportionate effect in the network meta-analyses, and considered putting additional weight on the findings of Aristodemou et al. (2011), due to the study's greater power and more inclusive population. For these reasons, the committee arrived at the view that surgeons should consider personalising their IOL constants. The evidence was not sufficiently unambiguous to make a firm ('offer') recommendation, but there was no prospect of patient harm resulting from the approach, and it should not be onerous for surgeons to incorporate this step into their audit routines (that is, the anticipated opportunity cost – in terms of surgeon time – is negligible). However, the committee agreed that no specific distinction could be made on the best optimisation strategy, given that all the credible intervals overlapped each other across all the assessed outcomes (mean absolute error and proportion of eyes within 0.25, 0.50 and 1.00 dioptres). Therefore, the committee agreed a recommendation that urges surgeons to consider personal optimisation, but leaves the specific strategy to the individual's discretion.
Consideration of health benefits and resource use	No health economic evidence was found for this review question, and it was not prioritised for *de novo* modelling work. The committee did not consider the recommendation made would have significant resource implications.
Quality of evidence	The committee noted the lack of randomised controlled trials examining the effectiveness of different IOL constant optimisation strategies. They highlighted that all the identified studies were retrospective in design such that assumptions were made that the preoperative data were accurate. The postoperative refractive outcome was used to back-calculate the likely outcomes given that various optimisation strategies had been applied. The committee noted that, with the exception of 1 large UK based study, the studies were small.

	The committee noted that 3 studies specifically stated that an autorefractor had been used to assess the postoperative refractive outcome. This is different to clinical practice in that auto-refraction is used as a baseline measurement and does not guide lens selection/corrective lens prescription. However, the committee agreed that, due to lack of detailed reporting, it was unclear as to whether other studies had only assessed subjective refraction postoperatively. The committee noted the general lack of descriptive detail of the optimisation methods applied in most of the studies, particularly ambiguity regarding the use of the Users Group for Laser Interference Biometry (ULIB) framework, which made it difficult to implement in clinical practice. The committee noted that, in many instances, the comparator arms may have also involved the use of optimised constants (for example, IOL constants available from optical biometry machines) but, because of the limited detail provided by the studies, it was unclear whether optimisation occurred. However, it agreed that these comparator arms could be grouped together in 1 category of standard IOL constants since it was clear that an optimisation strategy was being applied in the other arms, and given the retrospective nature of the study designs, all optimisation methods were compared with the original calculations undertaken on the same optical biometry machine. While the committee recognised that various confounding factors (for example, type of IOL and IOL formulas) were kept constant within studies, and that sensitivity analyses undertaken involving the removal of the study on light-adjustable lens had not affect the overall findings, it agreed that this specific study (Conrad-Hengerer et al. 2011) should be excluded from the evidence base because refraction could not be determined as being stable or accurate at the point of measurement. The committee agreed that the remaining 9 studies were adequately homogeneous to be included in a network meta-analysis and that the overall quality of evidence was low to moderate. They agreed that whilst the exclusion of participants with complications during surgery is likely to have led to overestimates in the effectiveness of biometry overall, there was no reason to believe this will have led to differences in the comparative effectiveness of the approaches.
Other considerations	No other considerations were identified for this review question.

7.3.7 Recommendations

15. Surgeons should think about modifying a manufacturer's recommended intraocular lens constant, guided by learning gained from their previous deviations from predicted refractive outcomes.

7.4 Other considerations in biometry

7.4.1 Review question

- What other factors should be considered such as, who should undertake biometry and when should preoperative biometry be assessed?

7.4.2 Introduction

The aim of this review was to identify other factors that should be considered to minimise the risk of biometry errors and postoperative refractive errors and in particular the following:

- who should undertake biometry
- when should preoperative biometry be assessed
- second eye prediction refinement.

The review focussed on identifying studies that fulfilled the conditions specified in Table 17. For full details of the review protocol, see Appendix C. The main outcome for this review question was the predictive accuracy of the different methods, assessed by deviations from the predicted refractive outcome expressed as a spherical equivalent. As suggested by Gale et al. (2009), a benchmark standard of 85% of individuals achieving a final spherical equivalent within 1.00 dioptre of the predicted refraction and 55% of individuals within 0.50 dioptres was used to evaluate the clinical relevance of the review findings.

Table 17: PICO inclusion criteria for the review question on other factors

Population	Adults (18 years and over) undergoing biometry prior to phacoemulsification cataract surgery with intraocular lens implantation
Interventions	• Who should undertake biometry • When should preoperative biometry be assessed • Second eye prediction refinement
Outcomes	• Deviation from predicted refractive outcome expressed as a spherical equivalent • Resource use and cost

Randomised controlled trials (RCTs) and observational studies comparing different methods of reducing the risk of biometry errors and postoperative refractive errors in adults undergoing phacoemulsification cataract surgery were included. Papers were excluded if they:

- were guidelines/health technology assessment reports, narrative reviews, case studies/reports, case series with less than 10 people, reliability studies, diagnostic accuracy studies, non-comparative studies
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- focused on combination surgical procedures that is, cataract surgery in tandem with other surgical procedures (for example, phacotrabeculectomy, canaloplasty, Descemet's stripping automated endothelial keratoplasty)
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

7.4.3 Evidence review

In total, 18,080 references were found for a combined database search for all 4 related review questions on biometry and postoperative refractive errors, with 315 articles ordered for full-text review. Four unique observational studies were included (Aristodemou et al.,

2011; Covert et al., 2010; Jabbour et al., 2006; Jivrajka et al., 2012), all focusing on second eye prediction refinement, that is using the first eye prediction error to adjust the intraocular lens (IOL) calculation for the second eye. Since these studies were in the form of intra-person comparisons (where every tested strategy was calculated for each individual in the study), it was agreed the usual concerns associated with using non-randomised data were not relevant here, and therefore observational studies were started as being high-quality evidence in the GRADE framework, and downgraded from that point. No relevant studies were identified for the other two listed factors, that is, staffing and timing of preoperative assessments.

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

7.4.3.1 Description of included studies

Details of the included studies are found in the evidence tables (see Appendix E).

7.4.3.1.1 Second eye prediction refinement

The 4 case series including a total of 2,291 participants (4,582 eyes; range n=97 to 1,867) undergoing bilateral sequential phacoemulsification cataract surgery were carried out in the UK (Aristodemou et al., 2011), USA (Covert et al., 2010; Jivrajka et al., 2012) and Germany (Jabbour et al., 2006). All but 1 study (Jivrajka et al., 2012) specifically stated that the surgery was conducted in 1 hospital. Timing between the first and second eye surgeries was not reported by Aristodemou et al. (2011), while Covert et al. (2010) reported a mean of 36.7 days, Jabbour et al. (2006) reported a median of 3 months and Jivrajka et al. (2012) provided a range of 1 to 3 months. All but 1 study (Jivrajka et al., 2012) used a retrospective design to develop and/or test various correction factors based on the first eye prediction error. One study did not report any baseline characteristics (Aristodemou et al., 2011). Two studies reported mean age, one specifically at the time of first eye surgery (69.9 years, Covert et al., 2010) and the other was unclear in terms of timing (77.57 years, Jivrajka et al., 2012). Three studies reported similar distributions of female patients (51% in Jivrajka et al., 2012 to 64% in Jabbour et al., 2006), mean axial lengths ranging from 23.15mm (Jabbour et al. 2006) to 24.0mm (Covert et al., 2010) and mean keratometric readings ranging from 43.48 dioptres (Jabbour et al., 2006) to 44.00 dioptres (Covert et al., 2010). Two studies specifically excluded people who had corneal astigmatism >3.00 dioptres (Aristodemou et al., 2011; Jabbour et al., 2006). All studies applied exclusion criteria based on concurrent procedures and/or ocular comorbidities. No studies provided information on specific diagnosis.

All but 1 study undertook biometry and keratometry measurements using the IOLMaster; Jabbour et al. (2006) used 2 ultrasound biometers and 2 identical Bausch & Lomb keratometers. Only 2 studies provided some information on the biometry assessors; Covert et al. (2010) noted that a trained ophthalmic technician carried out measurements, while Jabbour et al. (2006) highlighted that readings were taken by 2 different operators. All studies used different formulas. Aristodemou et al. (2011) used the Hoffer Q, Holladay I and SRK/T formulas based on the axial lengths of paired eyes, Covert et al. (2010) used the SRK-II and Holladay (1998) formulas, Jabbour et al. (2006) used the SRK/T and axial length vergence formulas while Jivrajka et al. (2012) used the Haigis formula.

All phacoemulsification cataract surgery was undertaken by the same surgeon for 3 studies, Aristodemou et al. (2011) did not provide any details. Only 3 studies reported timing of postoperative refractive assessment which varied from at least 4 weeks (Aristodemou et al., 2011; Covert et al. 2010) up to 8 weeks (Jivrajka et al., 2012). All but 1 study (Jivrajka et al., 2012) reported that subjective refraction was used at postoperative assessment.

All but 1 study (Jabbour et al., 2006) found that 50% was the optimal correction factor to take into consideration when applying the first eye prediction error.

The quality of the evidence ranged from very low to low (see Appendix G for the GRADE tables and Appendix H for the meta-analysis results).

7.4.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which none were retained for this review question. Health economic modelling was not prioritised for this review question.

7.4.5 Evidence statements

7.4.5.1 Second eye prediction refinement

Very low-quality evidence from 1 retrospective case series of 412 people found a small statistically significant between group difference in mean absolute prediction errors in favour of the 50% adjusted 2nd eye prediction group compared with the unadjusted 2nd eye prediction group.

Statistically significant between group differences were only observed in the proportion of individuals achieving postoperative refraction within 0.50 dioptres (80.3% with 50% adjusted 2nd eye prediction vs. 73.3% with unadjusted 2nd eye prediction) in 2 low-quality retrospective case series. No statistically significant differences were observed in the proportion of individuals achieving postoperative refraction within 1.00 dioptre (3 low quality case series; 96.3% with 50% adjusted 2nd eye prediction vs. 94.7% with unadjusted 2nd eye prediction).

7.4.5.2 Health Economic Evidence

No health economic evidence was identified for this review question.

7.4.6 Evidence to recommendations

Relative value of different outcomes	The Guideline committee agreed that the critical outcome for decision making was deviation from predicted refractive outcome, while resource use and costs were considered to be important.
Trade-off between benefits and harms	The committee discussed the implications of using first eye prediction error to inform calculations of intraocular lens power of the second eye in terms of adequate timing between the first and second eye surgeries to ensure that the refractive error of the first eye had stabilised. The committee noted that individuals undergoing bilateral simultaneous cataract surgery may be disadvantaged by recommending that second eye prediction is adjusted based on first eye prediction. However, the committee agreed that given the potential benefit of improved prediction of the second eye and subsequent improved patient outcomes such as satisfaction, the use of first eye prediction error to inform second eye prediction should be considered by healthcare professionals where appropriate, such as in cases where first eye prediction error does not result in 'refractive surprise' or require lens exchange. The committee agreed that, although the evidence base was of low quality, it did suggest that second eye prediction adjustment did lead to improved refractive outcomes, and it was highly unlikely there would be any negative outcomes that could result from doing so which would counterbalance these small gains.

Consideration of health benefits and resource use	No relevant health economic evidence was identified and *de novo* health economic modelling was not prioritised for this review question.
Quality of evidence	The committee noted that no relevant studies were identified to inform who should undertake biometry or when the preoperative biometry assessment should take place. The committee agreed that the evidence for the use of first eye prediction errors to inform second eye prediction refinement was generally of low quality because the majority of studies (3 out of 4) were retrospective in design, applying theoretical calculations, with no consideration of practical, clinical and individual implications such as anisometropia. However, the committee noted that the only small prospective study on 97 people showed similar evidence of beneficial effect of using 50% adjusted first eye prediction error to inform calculations of intraocular lens power of the second eye. The committee also noted that in 1 retrospective study, 50% adjusted refinement was shown to be beneficial even in situations where the intraocular lens constants in the formula were already optimised. The committee agreed that it would be useful to provide a clinical guide on the maximum threshold level of prediction error from the first eye for use in second eye prediction, in order to minimise the risk of anisometropia. However, the committee noted that the evidence reviewed did not facilitate recommendation with this detailed information.
Other considerations	The committee noted that currently individuals are routinely refracted postoperatively at 4-6 weeks but the outcome data are not necessarily provided to ophthalmology departments to enable consideration of adjustment for second eye surgery intraocular lens calculations. The committee noted that there is evidence to suggest that there is limited uptake of guidelines on the appropriate use of formulas, and therefore a recommendation to adjust second eye prediction based on first eye prediction errors would be useful in improving patient care. The committee noted that a range of professionals may undertake biometry but it is exceedingly important that staff are appropriately trained and experienced.

7.4.7 Recommendations

16. Consider using 50% of the first eye prediction error in observed refractive outcome to guide calculations for the intraocular lens power for second-eye cataract surgery.

7.5 Risk stratification and risk factors for increased cataract surgical complications

7.5.1 Review questions

- What is the effectiveness of risk stratification techniques to reduce surgical complications?
- What are the risk factors associated with increased surgical complications in cataract surgery?

7.5.2 Introduction

The aim of this review was to determine the effectiveness of preoperative risk stratification techniques, and the identification of risk factors associated with an increase in surgical complications. The reviews for these two separate issues focused on identifying studies that fulfilled the conditions specified in Table 18 and Table 19, respectively. For full details of the review protocol, see Appendix C. The main outcomes for this review were surgical complication rates.

Table 18 PICO for effectiveness of preoperative risk stratification techniques

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery with intraocular lens implantation
Interventions	• Preoperative risk stratification systems • Prioritised factors in ophthalmic risk stratification: • Pupil size • Density of lens • Age and mobility of patients • Ocular comorbidities e.g. macular degeneration, Fuch's, Corneal endothelial dystrophies, glaucoma, uveitis, pseudoexfoliation, big eyes, small eyes • Systemic comorbidities e.g. diabetes, hypertension, dementia and other mental illnesses • Tamsulosin and warfarin (anticoagulants) use
Outcomes	• Surgical complications rates • Resource use and cost

Papers were excluded if they:

- were narrative reviews, case studies/reports, commentaries, editorials/letters or opinion pieces.
- were studies on procedural safety surgical checklists e.g. WHO, case reports/case studies
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- reported studies conducted entirely in non-OECD countries
- were not published in the English language.

Table 19 PICO for risk factors that are associated with surgical complications

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery with intraocular lens implantation
Prognostic factors	• Pupil size • Density of lens • Age and mobility of patients • Ocular comorbidities e.g. macular degeneration, Fuch's, Corneal endothelial dystrophies, glaucoma, uveitis, pseudoexfoliation, big eyes, small eyes

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery with intraocular lens implantation
	• Systemic comorbidities e.g. diabetes, hypertension, dementia and other mental illnesses • Tamsulosin and warfarin (anticoagulants) use
Outcomes	• Surgical complications rates • Resource use and cost

Papers were excluded if they:

- were narrative reviews, case studies/reports, commentaries, editorials/letters or opinion pieces
- were studies on procedural safety surgical checklists e.g. WHO, case reports/case studies
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- reported studies conducted entirely in non-OECD countries
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

7.5.3 Evidence review

In total, 9,823 references were found from a combined database search for both review questions, and full-text versions of 67 citations that seemed potentially relevant to this topic were retrieved and screened at full-text. Four observational studies were included for risk stratification (Blomquist et al., 2010; Muhtaseb et al., 2004; Osbourne et al., 2006 and Tsinopoulos et al., 2013). Twelve studies (11 observational studies and 1 systematic review) were included for risk factors (Artzen et al., 2009; Beatty et al., 1998; Blomquist et al., 2012; Briszi et al., 2012; Chatziralli et al., 2011; Chen et al., 2010; Gonzalez et al., 2014; Keklikci et al., 2009; Ling et al., 2004; Narendran et al., 2009; Robbie et al., 2006 and Rutar et al., 2009).

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

7.5.3.1 Description of included studies

Summaries of the included studies for the review questions are given in Table 20 and Table 21, with full evidence tables available in Appendix E and GRADE tables available in Appendix G.

Table 20 Summary of included studies – risk stratification techniques

Study & location	Population	Methods
Blomquist (2010) USA Retrospective cohort	1,833 cataract surgery patients	Rating risk of complications in patients based on the Najjar-Awwad risk stratification score.
Muhtaseb (2004) UK Prospective cohort	1,000 cataract surgery patients	Patients allocated into risk groups based on the Muhtaseb risk stratification score.
Osbourne (2006) UK Case-control study	11,913 cataract surgery patients	Rating risk of complications in patients based on the Muhtaseb and Habib risk stratification scores.

Study & location	Population	Methods
Tsinopoulos (2013) Greece Randomised controlled trial	953 (1,109 eyes) cataract surgery patients	Rating risk of complications in patients based on the Muhtaseb risk stratification score.

Table 21 Summary of included studies – risk factors for surgical complications

Study & location	Population	Methods
Artzen (2009) Sweden Case-control study	655 cataract surgery patients	Comparison of capsule complications to case-controls
Beatty (1998) UK Case-control study	99 cataract surgery patients	Comparison of suprachoroidal haemorrhage to case-controls
Blomquist (2012) USA Retrospective cohort	2,434 cataract surgery patients	Comparison of patients with and without intraoperative complications
Briszi (2012) Germany Retrospective cohort	600 cataract surgery patients	Correlating patient characteristics risk factors to intraoperative complications
Chatziralli (2011) Greece Systematic review	17 studies (17,588 eyes)	Systematic review of risk factors for intraoperative floppy iris syndrome
Chen (2010) USA Retrospective cohort	59 people (81 eyes) cataract surgery patients	Comparison of prophylactic lidocaine-epinephrine to none on floppy-iris syndrome
Gonzalez (2014) Spain Prospective cohort	4,335 cataract surgery patients	Correlating patient characteristics risk factors to intraoperative and postoperative complications
Ling (2004) UK Case-control	558 cataract surgery patients	Comparison of suprachoroidal haemorrhage to case-controls
Narendran (2009) UK Prospective cohort	55,567 cataract surgery cases	Correlating patient characteristics risk factors to intraoperative complications
Robbie (2006) UK Prospective cohort	1,441 cataract surgery patients	Correlating patient age to intraoperative complications
Rutar (2009) USA Retrospective cohort	320 eyes of cataract surgery patients	Correlating patient characteristics risk factors to intraoperative complications

7.5.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references were retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

7.5.5 Evidence statements

7.5.5.1 Risk stratification techniques

Moderate-quality evidence from 1 retrospective cohort study of 1,883 participants found that those with a cataract risk score of >6 as determined using the Najjar–Awwad risk stratification algorithm have a clinically meaningfully increased risk of complications during cataract surgery.

Low- to high-quality evidence from 1 case-control study of 11,913 participants and 1 prospective cohort study of 1000 participants found that those with increasing potential complication scores as determined using the Muhtaseb risk stratification algorithm had clinically meaningfully higher odds of developing complications during cataract surgery.

Low-quality evidence from 1 case-control study of 11,913 participants found that those with increasing potential complication scores as determined using the Habib risk stratification algorithm had clinically meaningfully higher odds of developing complications during cataract surgery.

Very low- to low-quality evidence from 1 RCT of 953 participants could not distinguish rates of posterior capsule rupture or rates of all intraoperative complications between those in the risk stratified or unstratified arms of the trial.

Low-quality evidence from 1 RCT of 953 participants found, in the subgroup of participants operated on by trainee resident surgeons, clinically meaningfully lower odds of adverse events in the risk stratified as opposed to unstratified arm of the trial.

7.5.5.2 Risk factors

7.5.5.2.1 Risk of suprachoroidal haemorrhage

Low- to very low-quality evidence from 1 case-control study of 558 participants found those with a posterior capsule rupture, using cardiovascular drugs, with glaucoma, with increased preoperative intraocular pressure and those who undergo conversion from phacoemulsification to extracapsular cataract extraction during surgery had higher odds of developing a suprachoroidal haemorrhage during cataract surgery.

Very low-quality evidence from 1 case-control study of 99 participants could not differentiate preoperative intraocular pressure between those who did and did not develop a suprachoroidal haemorrhage during cataract surgery.

7.5.5.2.2 Risk of floppy iris syndrome

Low- to moderate-quality evidence from 1 retrospective cohort study of 59 participants found that those with a preoperative pupil diameter of ≤ 6.5 mm had higher odds of developing floppy iris syndrome during cataract surgery, but could not differentiate the odds between those receiving or not receiving prophylactic intracameral lidocaine-epinephrine.

Moderate- to high-quality evidence from 1 systematic review of 17,588 eyes found that people with hypertension had higher odds of developing floppy iris syndrome during cataract surgery, but could not differentiate the odds for people with diabetes mellitus.

Moderate-quality evidence from 1 systematic review of 17,588 eyes found that people using tamsulosin had higher odds of developing floppy iris syndrome during cataract surgery.

Moderate- to high-quality evidence from 1 systematic review of 17,588 eyes found that people using alfuzosin, terazosin or doxazosin had higher odds of developing floppy iris syndrome during cataract surgery.

7.5.5.2.3 *Risk of posterior capsule rupture, vitreous loss or both*

Moderate-quality evidence from 1 prospective cohort study of 55,567 participants found that those with the following preoperative characteristics had higher odds of developing posterior capsule rupture during cataract surgery:

- Glaucoma
- Diabetic retinopathy
- Brunescent / white cataract
- No fundal view / vitreous opacities
- Pseudo exfoliation / phacodonesis
- Pupil size (small)
- Axial length ≥ 26.0mm

Low- to moderate-quality evidence from 1 prospective cohort study of 55,567 participants found that, when compared with those operated on by a consultant, people who were operated on by the following surgical grade had higher odds of developing posterior capsule rupture during cataract surgery:

- Fellow
- Specialist registrar
- Senior house officer

but could not differentiate the odds for associate specialist or staff grade surgeons.

Low- to moderate-quality evidence from 1 prospective cohort study of 55,567 participants found that, when compared with those aged under 60 at the time of surgery, people over 70 had higher odds of developing posterior capsule rupture during cataract surgery, but could not differentiate the odds for ages 60–69.

Moderate-quality evidence from 1 prospective cohort study of 55,567 participants found that people who used doxazosin or were unable to lie flat for the operation had higher odds of developing posterior capsule rupture during cataract surgery.

7.5.5.2.4 *Risk of developing intraoperative complications*

Low-quality evidence from 1 prospective cohort study of 1,441 participants could not distinguish rates of intraoperative complications between those in different age groups.

Very low- to moderate-quality evidence from 1 retrospective cohort study found that people with preoperative white cataract or dense nuclear sclerosis had higher odds of developing intraoperative complications during cataract surgery but could not differentiate the odds for the following characteristics:

- Small pupil (< 6.0 mm)
- Anterior chamber depth < 2.5 mm
- Axial length > 26.0 mm
- Pseudoexfoliation syndrome
- Posterior synechia
- Restless patient

Moderate-quality evidence from 1 retrospective cohort study of 2,434 participants found that those with the following preoperative conditions had higher odds of developing intraoperative complications during cataract surgery:

- Worse corrected distance visual acuity (logMAR)
- Prior pars plana vitrectomy

- Dementia
- Zonular dehiscence

Very low-quality evidence from 1 retrospective cohort study of 320 participants could not distinguish rate of intraoperative complications between those with better and worse preoperative visual acuity.

Low- to very low-quality evidence from 1 prospective cohort study of 4,335 participants found that those with a preoperative visual acuity more than 1 logMAR had higher odds of developing intraoperative complications during cataract surgery than people with a preoperative visual acuity less than or equal to 0.3 logMAR.

Very low-quality evidence from 2 case-control studies of 1,255 participants found that having a preoperative white cataract increased the odds of developing intraoperative complications during cataract surgery.

Very low-quality evidence from 1 case-control study of 655 participants found that those with preoperative characteristics of phacodonesis or a brunescent/hard cataract had higher odds of developing intraoperative complications during cataract surgery, but could not differentiate the odds for those with corneal pathology or ocular comorbidity.

7.5.5.3 Health Economic Evidence

No health economic evidence was identified for this review question.

7.5.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed there were two important pieces of information which would inform any recommendations made. The first was whether risk-stratification algorithms were able to accurately predict individuals at higher risks of complications (and whether these algorithms stratified the risk of all complications or whether they were able to identify people at higher risk of specific complications). Secondly, it would be important to have information on whether the use of risk-stratification algorithms in practice leads to a reduction in overall complication rates, as the use of such algorithms would only be justified if it were to result in clinical benefit.
Trade-off between benefits and harms	The committee noted that the evidence presented and risk factors identified were largely in line with current clinical opinion and covered the major risk factors, including those posed from patients taking medication such as tamsulosin. The committee also noted that evidence regarding conversion rates from phacoemulsification to extracapsular cataracts extraction were likely to have changed over time with much fewer extracapsular cataract extraction operations taking place now. The committee agreed the evidence presented showed both that risk-stratification algorithms worked (that is, they were able to predict people at higher risk of complications) and that the use of an algorithm in an RCT demonstrated the potential to reduce complication rates. Specifically, the use of a risk-stratification algorithm, and the assignment of more complex cases to a more experienced surgeon led to a significant reduction in complication rates for trainee surgeons, without there being a significant increase in rates for the more experienced surgeons. The committee also agreed that since this evidence came from only 1 RCT using 1 particular risk stratification algorithm, that is was appropriate for this recommendation to be made at only the 'consider' level.

	The committee agreed there were a couple of unintentional downsides that could potentially occur as a result of the widespread adoption of risk-stratification. Firstly, while the assignment of more complex cases to more experienced surgeons should reduce the overall complication rate, it may result in more experienced surgeons having worse adverse event rates, which can cause problems when these rates are used to judge surgeon performance. It was noted that surgeon-specific complication rates are risk-adjusted when results are submitted and analysed, but this can only be done in cases where patients have been preoperatively risk-stratified. Secondly, the committee agreed that there is still a need to train the next generation of cataract surgeons and it could hamper teaching opportunities if they were not able to experience more complex surgeries. As a result of this, the committee agreed that it was appropriate that specific precautions were taken to maximise clinical outcomes in people at a high risk of complications. The surgeon training needs identified above meant that the committee agreed that it would not be appropriate to say these cases should not be assigned to surgeon in training, as this could lead to greater harms in the long-term from future surgeons not being fully trained, but felt it was appropriate to recommend that trainee surgeons should only undertake these more complex cases under the close supervision of an experienced surgeon. The committee also agreed there was another important subgroup of people, those with only 1 functional eye, where the consequences of a complication could be very severe and therefore again it was appropriate that trainee surgeons should only undertake these cases under the close supervision of an experienced surgeon.
Consideration of health benefits and resource use	The committee agreed that the use of risk-stratification algorithms was already widespread, and that the information needed did not represent anything that should not be considered as a part of the normal preoperative process. Therefore, there was not expected to be any substantial increase in resource use from these recommendations. The committee agreed the only way in which a significant increase in resource use might result was if the use of risk-stratification led to a higher proportion of cases being assigned to more experienced surgeons, but it was noted that the trial evidence did not seem to suggest this would be a likely result.
Quality of evidence	The committee agreed that, while the evidence on individual risk factors was generally of low quality, the fact it supported existing clinical opinion meant this was not a great cause of concern. It also noted that a number of risk-stratification algorithms had been tested in large groups of individuals with fairly consistent results, and this provided additional support to the committee's recommendations. It was, however, noted that there was only a single study which compared two risk-stratification algorithms against each other, and in the absence of more such data it was not felt to be appropriate to recommend the use of any specific algorithm, only that the one used should have been previously validated.
Other considerations	The committee agreed that some of the information coming out of this review also had implications for the conversations that should be had when an individual is deciding whether or not to have surgery. The committee discussed the evidence which indicated that patients with white, brunescent or hard cataracts were at an increased risk of intraoperative complications. It agreed that surgeons like to have greater illumination of the eyes features during surgery and, in patients with a denser cataract, it can be harder to see what you are doing, making the procedure more complex. It also noted that denser cataracts are harder to break up, take longer during surgery and those with denser cataracts tend to have worse visual acuity outcome

	after surgery. The committee also noted that, due to the progressive nature of most cataracts, a delay in the time of surgery may result in the cataract having hardened and therefore the person being at a higher risk of complications. The committee agreed that it was appropriate that individuals considering surgery should be given this information, as it may affect the risk–benefit balance of surgery for people with good vision in the other eye. The committee also agreed it was important that people be informed of the results of their individual risk-stratification, as these may impact the overall risk–benefit balance of surgery. It was, however, noted that making sure these results are communicated clearly and understood by the person was important, as otherwise they may cause unnecessary concern. In particular, there was concern that telling individuals they are at a higher risk of complications may cause them concern, even when the absolute level of risk is still very low. Therefore, the information provided to the individual should not just talk about their relative risk of complications compared with other people, but also the absolute level of risk, as this was felt to be easier to understand and more informative for most people.

7.5.7 Recommendations

17. **Consider using a validated risk stratification algorithm for people who have been referred for cataract surgery, to identify people at increased risk of complications during and after surgery.**

18. **Explain the results of the risk stratification to the person, and discuss how it may affect their decisions.**

19. **To minimise the risk of complications during and after surgery, ensure that surgeons in training are closely supervised when they perform cataract surgery in:**
    - people who are at high risk of complications **or**
    - people for whom the impact of complications would be especially severe (for example, people with only 1 functional eye).

20. **Explain to people who are at risk of developing a dense cataract that there is an increased risk of complications if surgery is delayed and the cataract becomes more dense.**

8 Intraocular lens selection

Polymethyl methacrylate (PMMA) lenses were the first type of intraocular lenses used after cataract surgery. These have been followed by silicone lenses, and more recently acrylic lenses, which can be either hydrophobic or hydrophilic. More modern lenses have tended to be foldable, in contrast to the rigidity of earlier PMMA lenses. Different lens materials may lead to different outcomes after surgery, including differences in rates of posterior capsule opacification, and different optical aberrations that may occur after surgery. Intraocular lenses may also have a rounded or square edge, which again may affect visual outcomes and rates of posterior capsule opacification after surgery.

Aspheric lenses have a more complex surface shape than spheric lenses, as the shape does not follow that of a sphere or cylinder. They are designed to reduce the level of spherical and other optical aberrations after surgery, and are also hypothesised to improve levels of contrast sensitivity after implantation, compared to spherical lenses.

All intraocular lenses in use today are designed to filter out ultraviolet light; these lenses are colourless and absorb most ultraviolet radiation and a small amount of violet light. Blue-light filtering lenses are designed to additionally block short-wavelength visible light – at the blue end of the spectrum. It has been hypothesised that age-related macular degeneration may, in part, be the result of cumulative retinal damage caused by phototoxicity from continued exposure to short-wavelength visible light. If this hypothesis is correct, blue-filtering lenses may play a role in reducing the incidence or progression of macular degeneration in people after cataract surgery, but this needs to be balanced against the potential loss of contrast sensitivity that the use of these lenses may cause.

Standard monofocal intraocular lenses, when implanted after cataract surgery have one single point of focus, meaning that a person's vision can only be optimised for either near or distance vision, but not both. People will then often require spectacles in order to see at whatever distance their lens has not been optimised for. Multifocal lenses are designed to have multiple points of focus and therefore improve vision and reduce rates of spectacle dependence, but there are concerns they may be associated with a range of optical abnormalities, including glare and halos. An alternative technique to attempt to optimise both near and distance vision is called monovision, where people have a monofocal lens optimised for near vision implanted in one eye, and a monofocal lens optimised for distance vision implanted in the other eye.

Toric intraocular lenses are designed to reduce postoperative astigmatism resulting from an abnormal curvature of the cornea. Toric lenses have a different refractive power in the horizontal and vertical plain, to counterbalance pre-existing visual distortions people may have. As well as the use of toric lenses, certain surgical techniques, such as limbal relaxing incisions and on-axis surgery, may also reduce levels of astigmatism by reshaping the cornea during surgery.

8.1 Lens design

8.1.1 Review questions

- Are different lens designs (aspheric vs. spheric, plate vs. loop) effective in improving postoperative vision (refractive outcomes, optical aberrations) in cataract surgery?
- Are different lens designs (square-edged vs. round-edge, plate vs. loop) and materials (hydrophilic acrylic, hydrophobic acrylic, collagen, hydroxyethyl methacrylate-based vs. silicone-based) effective in preventing posterior capsule opacification in cataract surgery?

8.1.2 Introduction

The aim of this review was to identify the most appropriate materials for and designs of intraocular lenses, both for improving visual outcomes and preventing posterior capsule opacification after cataract surgery.

The review focused on identifying studies that fulfilled the conditions specified in Table 22. For full details of the review protocol, see Appendix C. The main outcomes for this review were visual acuity, visual function and quality of life after surgery, surgical complication rates, patient satisfaction and resource use/costs.

Table 22: PICO inclusion criteria for lens material and design

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery with intraocular lens implantation
Interventions	Different monofocal lenses: • Aspheric vs. spheric • Plate vs. loop vs. 3 piece • Square-edged vs. round-edge • Hydrophilic acrylic vs. hydrophobic acrylic vs. PMMA-based vs. silicone-based
Outcomes	• Rates of posterior capsule opacification • Visual acuity • Visual function • Patient reported dysphotopsia (count data) • Night vision problems • Contrast sensitivity • Depth of focus • Near vision • Lens centration • Quality of life • Resource use and cost

Randomised controlled trials (RCTs) and systematic reviews of RCTs were included if they compared at least two different lenses which differed by a single one of the specified lens design features. Papers were excluded if they:

- compared monofocal with multifocal lenses
- only compared different lenses which did not differ in any of the specified features
- only compared different lenses which differed in more than one of the specified features
- were narrative reviews, case studies/reports, case series, reliability studies, diagnostic accuracy studies, non-comparative studies
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

8.1.3 Evidence review

In total, 1,830 references were found for these review questions, and full-text versions of 206 citations that seemed potentially relevant to this topic were retrieved. A Cochrane review containing 32 relevant RCTs was identified (other studies from the original review were excluded as they did not meet the criteria specified in our protocol), as were an additional 46 RCTs. The reference lists of 8 identified systematic reviews (Buehl et al. 2008, Cheng et al. 2007, Leung et al. 2014, Li et al. 2008, Li et al. 2013, Liu et al. 2013, Schuster et al. 2013, Schuster et al. 2015) were also reviewed to identify any additional relevant studies. Of the 78 RCTs included in the final review:

- 29 contained comparisons of different lens materials
- 23 contained comparisons of aspheric versus spheric lenses
- 18 contained comparison of 1-piece (loop or plate) versus 3-piece lenses
- 16 contained comparisons of square-edged versus round-edged lenses

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

Since the studies identified used a number of different scales to measure levels of posterior capsule opacification, all of the outcome measures were converted to a 0-100 scale before analysis, with higher numbers corresponding to worse levels of posterior capsule opacification.

8.1.3.1 Description of included studies

The included studies are summarised in Table 23; full details are found in the evidence tables (see Appendix E).

Table 23 Summary of included studies

Study & location	Population	Lens design comparison	Outcomes
Findl 2010 Cochrane review	32 relevant RCTs	Lens material Lens design	Visual acuity PCO YAG rate
Alio 2002 Spain	118 people with chronic uveitis (inter-person comparison)	PMMA vs hydrophobic acrylic vs silicone	YAG rate
Baumeister 2005 Germany	53 people (fellow-eye study)	Square-edge vs round-edge Hydrophobic acrylic vs silicone	Lens decentration Lens tilt
Baumeister 2009 Germany	21 people (fellow-eye study)	Aspheric vs spheric	Aberrations
Caporossi 2007 Italy	100 people (inter-person comparison)	Aspheric vs spheric	Visual acuity Aberrations Contrast sensitivity
Chang 2013 Sweden	80 people (inter-person comparison)	1-piece vs 3-piece	PCO YAG rate Glistenings
Chang 2015	78 people (fellow-eye study)	Hydrophobic acrylic vs hydrophilic acrylic	Glistenings

Study & location	Population	Lens design comparison	Outcomes
Sweden			
Chen 2006 China	20 people (fellow-eye study)	Aspheric vs spheric	Visual acuity Contrast sensitivity
Crnej 2014 Austria	30 people (fellow-eye study)	Aspheric vs spheric	Visual acuity PCO Contrast sensitivity
Cui 2009 China	57 people (inter-person comparison)	Aspheric vs spheric	Aberrations Contrast sensitivity
Denoyer 2007 France	20 people (inter-person comparison)	Aspheric vs spheric	Visual acuity Aberrations Contrast sensitivity
Espindola 2012 Brazil	25 people (fellow-eye study)	Aspheric vs spheric	Visual acuity Aberrations Contrast sensitivity
Findl 2015 UK and Austria	50 people (fellow-eye study)	1-piece vs 3-piece	Visual acuity PCO YAG rate
Hayashi 1997 Japan	160 people (inter-person comparison)	Hydrophobic acrylic vs silicone	Lens decentration Lens tilt
Hayashi 1998 Japan	100 people (fellow-eye study)	1-piece vs 3-piece	Lens decentration Lens tilt
Hayashi 2001 Japan	100 people (fellow-eye study)	Hydrophobic acrylic vs hydrophilic acrylic	YAG rate Lens decentration Lens tilt
Hayashi 2005 Japan	56 people (fellow-eye study)	1-piece vs 3-piece	Lens decentration Lens tilt
Hennig 2014 Nepal	1,200 people (inter-person comparison)	PMMA vs hydrophilic acrylic	Visual acuity PCO
Hollick 1999 UK	81 people (inter-person comparison)	PMMA vs hydrophilic acrylic vs silicone	YAG rate
Jafarinasab 2010 Iran	34 people (inter-person comparison)	Aspheric vs spheric	Visual acuity Aberrations Contrast sensitivity
Kobayashi 2000 Japan	1,202 people (inter-person comparison)	PMMA vs hydrophobic acrylic	Visual acuity YAG rate
Kucuksumer 2000 Turkey	50 people (fellow-eye study)	Hydrophobic acrylic vs hydrophilic acrylic	Visual acuity PCO YAG rate
Kugelberg 2008 Sweden	120 people (inter-person comparison)	Hydrophobic acrylic vs hydrophilic acrylic	Visual acuity YAG rate
Luo 2010 China	260 people (inter-person comparison)	Aspheric vs spheric	Visual acuity Contrast sensitivity

Study & location	Population	Lens design comparison	Outcomes
Moorfields 2007 UK	300 people (inter-person comparison)	Aspheric vs spheric	Visual acuity Aberrations Contrast sensitivity
Morales 2011 Brazil	40 people (fellow-eye study)	Aspheric vs spheric	Visual acuity Aberrations
Mutlu 2005 Turkey	88 people (inter-person comparison)	1-piece vs 3-piece	Lens decentration Lens tilt
Mylonas 2013 Austria	28 people (fellow-eye study)	1-piece vs 3-piece	PCO YAG rate
Nanavaty 2009 UK	47 people (fellow-eye study)	Aspheric vs spheric	Visual acuity Aberrations Depth of focus
Nanavaty 2012 UK	47 people (fellow-eye study)	Aspheric vs spheric	Visual acuity PCO YAG rate
Papaliodis 2002 USA	36 people with chronic uveitis (inter-person comparison)	PMMA vs hydrophobic acrylic vs silicone	YAG rate
Prinz 2011 Austria	40 people (fellow-eye study)	Plate vs 3-piece	Visual acuity PCO YAG rate Lens tilt
Prinz 2012 Austria	40 people (fellow-eye study)	1-piece vs 3-piece	Visual acuity PCO YAG rate
Rocha 2006 Brazil	60 people (fellow-eye study)	Aspheric vs spheric	Visual acuity Aberrations Contrast sensitivity
Roesel 2008 Germany	60 people with chronic uveitis (inter-person comparison)	Hydrophobic acrylic vs hydrophilic acrylic	Visual acuity PCO YAG rate
Sandoval 2008 USA	27 people (inter-person comparison)	Aspheric vs spheric	Visual function Contrast sensitivity
Santhiago 2010 Brazil	25 people (fellow-eye study)	Aspheric vs spheric	Visual acuity Contrast sensitivity
Shentu 2008 China	196 people (inter-person comparison)	Aspheric vs spheric	Visual acuity Contrast sensitivity
Takmaz 2009 Turkey	60 people (inter-person comparison)	Aspheric vs spheric	Aberrations Contrast sensitivity
Trueb 2009 Switzerland	262 people (inter-person comparison)	Aspheric vs spheric	Visual acuity Contrast sensitivity
Tzelikis 2007 Brazil	25 people (fellow-eye study)	Aspheric vs spheric	Visual acuity Aberrations

Study & location	Population	Lens design comparison	Outcomes
			Contrast sensitivity
Tzelikis 2008 Brazil	25 people (fellow-eye study)	Aspheric vs spheric	Visual acuity Aberrations Contrast sensitivity
van Gallan 2010 Netherlands	30 people (fellow-eye study)	Aspheric vs spheric	Visual acuity Aberrations
Vasavada 2011 India	68 people (fellow-eye study)	Hydrophobic acrylic vs hydrophilic acrylic	YAG rate
Vock 2009 Austria	22 people (fellow-eye study)	Hydrophobic acrylic vs silicone	Visual acuity YAG rate
Yamaguchi 2011 Japan	92 people (inter-person comparison)	Aspheric vs spheric	Contrast sensitivity
Zemaitiene 2011 Lithuania	89 people (inter-person comparison)	Hydrophobic acrylic vs silicone 1-piece vs 3-piece	Visual acuity PCO YAG rate
Zeng 2007 China	124 people (inter-person comparison)	Aspheric vs spheric	Visual acuity Contrast sensitivity

8.1.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references were retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

8.1.5 Evidence statements

8.1.5.1 PMMA versus silicone

Low-quality evidence from up to 8 RCTs containing 520 eyes could not differentiate levels of posterior capsule opacification or rates of Nd:YAG capsulotomy between people given PMMA or silicone intraocular lenses.

8.1.5.2 PMMA versus hydrophilic acrylic

Moderate-quality evidence from 1 RCT containing 996 eyes could not differentiate levels of uncorrected or corrected visual acuity between people given PMMA or hydrophilic acrylic intraocular lenses.

Moderate-quality evidence from 1 RCT containing 53 eyes found lower levels of posterior capsule opacification in people given PMMA compared with hydrophilic acrylic intraocular lenses, but moderate-quality evidence from 1 RCT containing 996 eyes found clinically meaningfully lower rates of Nd:YAG capsulotomy in people given hydrophilic acrylic versus PMMA intraocular lenses.

8.1.5.3 PMMA versus hydrophobic acrylic

Moderate-quality evidence from 1 RCT containing 909 eyes could not differentiate levels of corrected visual acuity between people given PMMA or hydrophobic acrylic intraocular lenses.

Low- to high-quality evidence from up to 5 RCTs containing 1,160 eyes found lower levels of posterior capsule opacification and clinically meaningfully lower rates of Nd:YAG capsulotomy in people given hydrophobic acrylic versus PMMA intraocular lenses, but could not differentiate rates of Nd:YAG capsulotomy for the subpopulation of people with pre-existing uveitis.

8.1.5.4 Hydrophobic acrylic versus silicone

Low- to moderate-quality evidence from up to 4 RCTs containing 318 eyes could not differentiate levels of corrected visual acuity, lens decentration or lens tilt between people given hydrophobic acrylic or silicone intraocular lenses.

Moderate- to high-quality evidence from up to 10 RCTs containing 1,088 eyes could not differentiate levels of posterior capsule opacification or rates of Nd:YAG capsulotomy between people given hydrophobic acrylic or silicone intraocular lenses.

8.1.5.5 Hydrophobic acrylic versus hydrophilic acrylic

Moderate- to high-quality evidence from up to 3 RCTs containing 217 eyes found higher levels of corrected visual acuity in people without pre-existing uveitis given hydrophobic acrylic versus hydrophilic acrylic intraocular lenses, but could not differentiate levels for people with pre-existing uveitis.

Low- to high-quality evidence from up to 3 RCTs containing 154 eyes found lower levels of posterior capsule opacification in people given hydrophobic acrylic versus hydrophilic acrylic intraocular lenses.

Low- to high-quality evidence from up to 8 RCTs containing 787 eyes found clinically meaningfully lower rates of Nd:YAG capsulotomy in people without pre-existing uveitis given hydrophobic acrylic versus hydrophilic acrylic intraocular lenses, but could not differentiate rates for people with pre-existing uveitis.

Moderate-quality evidence from 1 RCT containing 186 eyes could not differentiate levels of lens decentration or lens tilt between people given hydrophobic acrylic versus hydrophilic acrylic intraocular lenses.

Low-quality evidence from 1 RCT containing 78 eyes found more glistenings in people given hydrophobic acrylic versus hydrophilic acrylic intraocular lenses, but could not find any link between glistenings and either visual acuity or contrast sensitivity.

8.1.5.6 Network meta-analyses (lens material)

Moderate-quality evidence from 2 network-meta analyses of up to 12 RCTs containing 1,472 eyes found that hydrophilic acrylic and PMMA lenses were associated with significantly higher PCO scores than hydrophobic acrylic or silicone lenses, and hydrophilic acrylic lenses were associated with significantly higher scores than PMMA lenses.

Moderate-quality evidence from a network-meta analysis of 20 RCTs containing 2,900 eyes found that hydrophilic acrylic and PMMA lenses were associated with clinically meaningfully higher rates of Nd:YAG capsulotomy than hydrophobic acrylic or silicone lenses.

8.1.5.7 Square-edge versus round-edge

Moderate-quality evidence from up to 5 RCTs containing 460 eyes could not differentiate levels of corrected visual acuity, lens decentration or lens tilt between people given square-edge versus round-edge intraocular lenses.

Moderate- to high-quality evidence from up to 12 RCTs containing 1,393 eyes found lower levels of posterior capsule opacification and rates of Nd:YAG capsulotomy in people given square-edge versus round-edge intraocular lenses.

8.1.5.8 Loop versus 3-piece

Low- to moderate-quality evidence from up to 5 RCTs containing 278 eyes could not differentiate levels of uncorrected visual acuity, corrected visual acuity, lens decentration or lens tilt between people given loop or 3-piece intraocular lenses.

Moderate-quality evidence from up to 13 RCTs containing 1,212 eyes could not differentiate levels of posterior capsule opacification or rates of Nd:YAG capsulotomy between people given loop or 3-piece intraocular lenses.

Low-quality evidence from 1 RCT containing 78 eyes found more glistenings in people given loop versus 3-piece intraocular lenses, but could not find any link between glistenings and either visual acuity or contrast sensitivity.

8.1.5.9 Plate versus 3-piece

Moderate-quality evidence from 1 RCT containing 60 eyes could not differentiate levels of corrected visual acuity or lens tilt between people given plate or 3-piece intraocular lenses.

Low- to moderate-quality evidence from 1 RCT containing 60 eyes could not differentiate levels of posterior capsule opacification or rates of Nd:YAG capsulotomy between people given plate or 3-piece intraocular lenses.

8.1.5.10 Aspheric versus spheric

Moderate- to high-quality evidence from up to 16 RCTs containing 1,675 eyes could not identify and meaningful differences in levels of uncorrected or corrected visual acuity between people given aspheric or spheric intraocular lenses.

Low- to moderate-quality evidence from up to 2 RCTs containing 121 eyes could not differentiate levels of posterior capsule opacification or rates of Nd:YAG capsulotomy between people given aspheric or spheric intraocular lenses.

Low- to moderate-quality evidence from up to 14 RCTs containing 932 eyes found lower levels of spherical, higher-order and comatic aberrations in people given aspheric versus spheric intraocular lenses.

Moderate- to high-quality evidence from up to 3 RCTs containing 309 eyes found lower levels of depth of focus in people given aspheric versus spheric intraocular lenses, but could not differentiate levels of visual-function (measured using the VFQ-25) or contrast sensitivity (measured using the Pelli-Robson chart)

Low-quality evidence from up to 17 RCTs found higher levels of contrast sensitivity across all spatial frequencies tested in people given aspheric versus spheric intraocular lenses, with the difference being greater at mesopic lighting levels.

8.1.5.11 Health Economic Evidence

No health economic evidence was identified for this review question.

8.1.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed there were two key outcomes for this review. The first was rates of posterior capsule opacification, and the second was visual outcomes that impact on the quality of life of the individual. They agreed that, just because there was a measurable difference in some outcomes between different lenses, this did not mean the outcome would necessarily be important, as there are many features it is possible to measure which may make little or no difference to the majority of individuals.
Trade-off between benefits and harms	**Lens materials** The committee noted that hydrophobic acrylic and silicone lenses tended to perform better than PMMA lenses. They noted that PMMA lenses were now rarely used due to the established superiority of more modern designs, a finding confirmed in this review. They also noted the evidence of a clear benefit of hydrophobic acrylic and silicone over hydrophilic acrylic for reducing posterior capsule opacifications. However, it was noted that hydrophobic acrylic lenses were associated with more glistenings than hydrophilic acrylic lenses and, while the evidence did not show a link between glistenings and quality of life, the committee expressed concern that the studies were not sufficiently powered to show these differences. It was also noted that, while posterior capsule opacification can be successfully treated with a YAG capsulotomy, there is currently no method to treat glistenings caused by hydrophobic acrylic lenses. However, the committee agreed these concerns did not override the clear benefits seen in rates of posterior capsule opacification, and therefore agreed the evidence supported an 'offer' recommendation for hydrophobic acrylic and silicone lenses, for the purpose of reducing rates of posterior capsule opacification. **Square-edge versus round-edge** The committee agreed that the evidence presented demonstrated that square-edge lenses result in lower rates of posterior capsule opacification, and that an 'offer' recommendation was justified on this basis. The committee noted there is an increased risk of dysphotopsia with square-edge lenses, an adverse event that was not consistently captured in the evidence base, but again felt this did not override the benefits seen in reduced PCO rates. It was also noted that, while the evidence was divided into square-edge and round-edge lenses, there is a considerable degree of variability in 'how square' a square-edge lens is. In particular, square-edge hydrophilic acrylic lenses may have less square edges than square-edge hydrophobic lenses, which may introduce an element of confounding. **1-piece versus 3-piece** The committee agreed there was no evidence to suggest important differences between 1-piece (loop or plate) and 3-piece lenses, and therefore agreed that a recommendation was not necessary. It was noted that lens design is currently moving in the direction of 1-piece lenses, and these are likely to become the predominant design moving forwards. **Aspheric versus spheric** The committee agreed there was clear evidence of benefits in levels of aberrations and contrast sensitivity with aspheric lenses, and evidence of benefits in depth of focus with spheric lenses. However, the relationship between these outcomes and either overall visual function or quality of life was unclear, and therefore the committee was unable to prioritise the importance of these different outcomes. They agreed that, although there was a statistically significant benefit in visual acuity with aspheric lenses, the magnitude of this benefit (between 0 and 1 letters on a Snellen chart) was too small to

	represent a clinically meaningful benefit. Therefore, it was agreed that, with the current evidence, both spheric and aspheric lenses were legitimate options, but future research was necessary looking at the relative importance of the different outcomes. They agreed such research, looking at the impact of contrast sensitivity and depth of focus on quality of life, would be of more value than additional RCTs comparing these lens types, as more uncertainty remained in the relative value of the outcomes than in what the difference is in outcomes between the different lens types.
Consideration of health benefits and resource use	The committee discussed whether there were likely to be any resources implications from recommendations about different lens designs. It was noted that when manufacturers attempted to persuade hospitals to move to using alternative lenses, they usually offer the new lenses at the same price as the lens currently in use by the surgery. On this basis it would be unlikely for there to be any resource implications from changes in practice with regard to switching preferred lens designs.
Quality of evidence	The committee agreed that the overall quality of evidence was high for short-term visual outcomes, but considerably lower for longer-term outcomes. They therefore made a research recommendation around long-term follow-up of different lens materials, and specified a range of patient-important outcomes and adverse events that should be captured, to ensure that all the necessary data were collected to weigh up the necessary trade-offs between options. It was also noted that, since lens design is advancing rapidly, there are likely to be newer designs available that have not yet been evaluated in randomised controlled trials. It was also agreed, on the same basis, that a register of reasons for lens explantation would provide value to future research, as this would provide an objective measure of when problems with lens choice are sufficiently severe that it is necessary for the person to undergo a second operation for the purposes of inserting a different type of lens. The committee noted that the evidence base contained some studies using inter-person comparisons (with individuals being randomised to one lens or the alternative), and some using fellow-eye comparisons (where an individual with bilateral cataracts is randomised to have one type of lens in one eye and an alternative in the other). The committee agreed these were both appropriate methods of randomisation in studies of cataract surgery, and felt it was appropriate to combine data from the two study types, as there would not be expected to be a difference in the mean effect size between the two methods.
Other considerations	Since a number of the decisions about lens material/design rely on difficult trade-offs between benefits and harms, an ideal solution to this would be to allow patients to choose on a case-by-case basis which option they would prefer. However, the committee did not feel they were able to make such a recommendation for 2 reasons. First, many of the trade-offs rely on complex concepts (e.g. spherical and higher-order aberrations) that would not be easy to explain to someone who has never experienced them. Secondly, most surgeries have contracts with lens suppliers which give a discount price but only supply one type of lens. Therefore, surgeries would not have a stock of different lens choices from which people would be able to pick. The committee therefore agreed that these recommendations needed to be aimed more at surgeons picking a type of lens to keep in stock than at individuals choosing a lens type for themselves.

8.1.7 Recommendations

21. Offer square-edged hydrophobic acrylic or silicone intraocular lenses to people having cataract surgery, to reduce the risk of posterior capsule opacification.

8.1.8 Research recommendations

6. What are the long-term outcomes of different choices of intraocular lens material following cataract surgery?

Why is this important?

Although there is high-quality evidence for the short-term visual outcomes and adverse event risks of different intraocular lens materials, there is a lack of evidence for longer-term outcomes. Lens design is advancing rapidly, and there are likely to be new designs becoming available in the near future that have not yet been evaluated. Well conducted long-term randomised controlled trials reporting patient-important outcomes and adverse events would help to inform future recommendations on lens material choices for use in cataract surgery, in particular the trade-offs between visual outcomes and adverse events with different lens materials.

7. What are the long-term rates of and reasons for lens explantation after cataract surgery?

Why is this important?

The development of a register of lens explantations would help to explore if a particular lens type needed to be explanted more than others, and allow the determination of when these take place and the reasons behind them. Such evidence would enhance understanding of possible issues pertinent to cataracts surgery, in particular whether there are certain lens types associated with rare but significant problems, either adverse events or dissatisfaction with visual outcomes, which require another surgical procedure to correct.

8. What is the effect of differences in contrast sensitivity and depth of focus on overall visual function and quality of life?

Why is this important?

This guideline identified differences in contrast sensitivity and depth of focus between different lens designs, but there was not good evidence linking these intermediate outcomes to either patient satisfaction or quality of life. Cross-sectional or cohort studies that looked at the correlations between contrast sensitivity/depth of focus and quality of life would help to better interpret the results from these clinical studies, and make it possible to judge whether these differences, which are clinically measurable, are actually meaningful to the individuals concerned.

8.2 Tinted vs colourless lenses

8.2.1 Review question

- Are tinted lenses effective in preventing the progression of age-related macular degeneration compared with colourless lenses in cataract surgery?

8.2.2 Introduction

The aim of this review was to determine whether tinted lenses are effective in preventing the progression of age related macular degeneration (AMD) compared with colourless lenses. Colourless lenses (ultraviolet light blocking) are also referred to within the included studies as 'Neutral, Natural or Clear'. The term used is dependent on the author but they are comparable. The review focused on identifying studies that fulfilled the conditions specified in Table 24. For full details of the review protocol, see Appendix C. The main outcomes for this review were age related macular degeneration, visual acuity, colour vision and sleep problems.

Table 24 PICO inclusion criteria for the review question on tinted versus colourless lenses

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery with intraocular lens implantation
Interventions	• Different monofocal/multifocal lenses • Tinted vs. colourless • Different colours
Outcomes	• Incidence of age-related macular degeneration • Rates of progression of age-related macular degeneration • Visual acuity • Colour vision • Sleep problems • Depression • Quality of life • Resource use and cost

Papers were excluded if they:

- were narrative reviews, case studies/reports, commentaries, editorials/letters or opinion pieces
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

8.2.3 Evidence review

In total, 524 references were found from a database search for the review question, and full-text versions of 44 citations that seemed potentially relevant to this topic were retrieved and screened at full-text. Five studies (1 systematic review containing 15 RCTs and 4 additional randomised controlled trials) were included (Brondsted et al., 2015; Espindle et al., 2005; Kara-Junior et al., Marshall et al. 2005; Zhu et al. 2012). One further paper was included after a re-run of the searches for this review question (Brondsted et al., 2016).

None of the additional studies identified provided data on any of the outcomes included in the Zhu systematic review, and therefore the results for those outcomes are taken directly from the Zhu review, rather than from the primary studies.

8.2.3.1 Description of included studies

The design of included studies is summarised in Table 25. Full details and results are found in the evidence tables (see Appendix E).

Table 25 Summary of included studies – tinted versus colourless lenses

Study & location	Population	Methods
Barisic (2007) Croatia	60 patients	RCT comparing visual function in patients with blue light filtering IOL's compared with natural IOL's. Citation found within Zhu (2012) Systematic Review
Brondsted (2015) USA	76 patients	RCT determining the effect of cataract surgery on circadian photoentrainment when receiving blue-blocking or neutral IOL's
Brondsted (2016) Denmark	67 patients	RCT determining the effect of blue-blocking and neutral intraocular lenses on circadian photoentrainment and sleep one year after cataract surgery.
Caporossi (2007) Italy	50 patients	RCT comparing the performance of 3 aspheric and 2 spherical IOL's. Citation found within Zhu (2012) Systematic Review
Caporossi (2009) Italy	50 patients	RCT comparing aspheric and spherical IOL's 2 years after implantation on visual function. Citation found within Zhu (2012) Systematic Review
Espindle (2005) USA	257 patients	RCT comparing quality of life improvements in patients with blue light filtering IOL's compared with clear IOL's
Hayashi (2006) Japan	74 patients	RCT comparing the visual function in patients with short wavelength blue light blocking yellow tinted intraocular lenses (IOLs) with that in patients with non-tinted IOLs. Citation found within Zhu (2012) Systematic Review
Kara-Junior (2011) Brazil	25 patients	RCT comparing colour vision in patients with blue light filtering IOL's compared with clear IOL's
Leibovich (2006) Australia	19 patients	RCT comparing the visual outcomes in patients with blue light filtering or natural IOL's. Citation found within Zhu (2012) Systematic Review
Marshall (2005) USA	297 patients	RCT comparing visual function in patients with blue light filtering IOL's or clear IOL's.
Mester (2008) Germany	47 patients	RCT comparing the visual outcomes in patients with blue light filtering with a yellow chromophore or clear IOL's. Citation found within Zhu (2012) Systematic Review
Neumaier-Ammerer (2010) Austria	80 patients	RCT comparing visual performance with blue light filtering and ultraviolet light filtering intraocular lenses. Citation found within Zhu (2012) Systematic Review
Pandita (2007) India	80 patients	RCT comparing visual function in patients with blue light filtering IOL's compared with natural IOL's. Citation found within Zhu (2012) Systematic Review

Study & location	Population	Methods
Rocha (2007) Brazil	40 patients	Citation found within Zhu (2012) Systematic Review *Awaiting copy of paper
Schmidinger (2008) Austria	31 patients	RCT comparing the visual outcomes in patients with blue light filtering with a yellow chromophore or clear IOL's. Citation found within Zhu (2012) Systematic Review
Vuori (2006) Finland	37 patients	Citation found within Zhu (2012) Systematic Review *Awaiting copy of paper
Wang (2010) China	79 patients	RCT comparing visual function in patients with blue light filtering photochromic IOL's compared with yellow blue light filtering IOL's and clear IOL's. Citation found within Zhu (2012) Systematic Review
Wirtitsch (2009) Austria	24 patients	RCT comparing the colour perception in patients with blue light filtering or neutral IOL's. Citation found within Zhu (2012) Systematic Review
Zhu (2012) China	15 RCT studies	Systematic Review comparing blue light-filtering IOLs and UV light-filtering IOLs for cataract surgery.

8.2.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references were retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

8.2.5 Evidence statements

High-quality evidence from 4 RCTs containing 333 eyes found that people offered a UV-light-filtering lens had better postoperative colour vision in the blue light spectrum under mesopic (low light level) conditions compared with those offered a blue-light-filtering lens during cataract surgery.

Very low- to moderate-quality evidence from up to 8 RCTs containing 647 eyes could not differentiate levels of postoperative colour vision under photopic (high light level) conditions sleep efficiency, sleep quality, visual acuity, colour perception, colour discrimination, macular thickness or quality of life between people offered either a UV-light-filtering or blue-light-filtering lens during cataract surgery.

8.2.5.1 Health Economic Evidence

No health economic evidence was identified for this review question.

8.2.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that the 2 key outcomes to inform this question were any differences in the incidence or progression of age-related macular degeneration, and overall vision- and health-related quality of life. It was agreed that, if tinted lenses could demonstrate improvements in macular degeneration without significantly affecting quality of life, then this would be good evidence for their use. Other outcomes where the committee noted that meaningful differences

	could be detected were colour vision and sleep quality, though the committee agreed that ideally these outcomes would then be evaluated to see if they impacted on quality of life.
Trade-off between benefits and harms	The committee noted there are longstanding theoretical arguments for why blue-light-filtering lenses may have benefits for preventing macular degeneration. However, the committee agreed that there was currently no empirical evidence to suggest a clinical difference between implanting blue-light-filtering intraocular lenses compared with ultraviolet light filtering. In particular, it noted that there was a lack of studies that have or that are being undertaken to look specifically at the effect of blue-light-filtering lenses on the incidence and/or progression of AMD after cataract surgery. Although the protocol for this review looked specifically at randomised controlled trials, it was agreed that expanding the criteria to other study designs would be unlikely to provide useful evidence. The only studies that look at macular degeneration incidence with blue-light-filtering versus UV-light-filtering lenses are only available as conference abstracts showing no differences between groups, with these results never published as full papers. Although the committee could not make a positive recommendation from the evidence presented, it agreed that, because of the theoretical arguments for the benefits these lenses might have, long-term research studies measuring the progression of AMD were needed and felt this was an important research recommendation to make. Further, they agreed that since there was evidence of potential harms (in particular on colour vision), it was appropriate for these lenses only to be used as part of clinical studies until such time as either benefit, harm or equivalence was definitively established. Due to the lack of specific research looking at AMD and cataract surgery, the committee agreed that the measurement of macular thickness would be of benefit to the evidence base. The one identified RCT reporting macular thickness did not show any differences between the groups (again providing no support for a positive recommendation), but the study follow-up was not long enough to provide conclusive data.
Consideration of health benefits and resource use	The committee discussed whether there were likely to be any resource implications from either recommending or not recommending tinted lenses. It was noted that in the experience of the committee members, when manufacturers attempt to persuade surgeries to move to using blue-light-filtering lenses, they usually offer the new lenses at the same price as the lens currently in use by the surgery. On this basis it would be unlikely for there to be any resource implications from changes in practice with regard to the use of blue-light-filtering versus UV-light-filtering lens.
Quality of evidence	The committee agreed that the overall quality of the evidence, for measuring short-term visual outcomes, was reasonable and demonstrated there was worse colour vision at low light levels with tinted lenses, but no other significant negative consequences from their use. However, the almost total absence of useful data on macular degeneration outcomes meant the evidence was of little use in addressing the actual underlying question being asked of whether these lenses may prove protective against the onset of macular degeneration. The committee noted that many studies relied upon using the Farnsworth–Munsell hue test in order to measure colour vision outcomes. Committee members expressed concern in relying on this evidence as the test was originally developed to measure colour vision in young people with normal lenses or normal lenses with

	spectacles and not for testing colour vision in adults thus may not be applicable to the full population studied. The committee agreed that, although the exclusion criteria in the trials seemed extensive, they were reasonable and unlikely to impact on the overall pattern of the evidence.
Other considerations	None identified

8.2.7 Recommendations

22. Do not use blue-light filtering intraocular lenses in cataract surgery, unless as part of a research study.

8.2.8 Research recommendations

9. What is the long-term effectiveness of blue light filtering IOLs in reducing the incidence and/or progression of age-related macular degeneration?

Why is this important?

There is a lack of evidence on the long term effectiveness of blue light filtering lenses with regards to the incidence or progression of age-related macular degeneration. Combined with the evidence of some harms from these lenses, specifically on colour vision, this makes it difficult at present to justify the use of these lenses in clinical practice. Well conducted long term randomised controlled trials and longitudinal studies in this area, which should measure macular degeneration incidence and progression as their primary outcome measures, would help to add to the evidence base in this area of research and so inform future recommendations on their use.

8.3 Multifocal vs monofocal intraocular lenses

8.3.1 Review question

- What is the optimal strategy to facilitate simultaneous distance and near vision following cataract surgery?

8.3.2 Introduction

Reviews of multifocal lenses versus monofocal lenses, and multifocal lenses versus monovision, were undertaken by the Cochrane Eyes and Vision Group, in collaboration with the NICE Internal Clinical Guidelines Team. The NICE Internal Clinical Guidelines Team then searched for additional evidence on monofocal lenses versus monovision, bifocal versus trifocal lenses, and refractive versus diffractive multifocal lenses.

The aim of the review question was to determine the effects of multifocal compared with monofocal intraocular lenses following cataract surgery from RCTs, and the comparative effectiveness of different designs of multifocal lens. The review focused on identifying studies that fulfilled the conditions specified in Table 26. For full details of the review protocol, see Appendix C.

Table 26: PICO criteria – optimal strategies to facilitate simultaneous distance and near vision

Population	Adults (18 years and older) undergoing phacoemulsification cataract surgery and intraocular lens (IOL) implantation in one or both eyes
Interventions	1. Any type of non-accommodative multifocal intraocular lenses (including toric multifocal lenses) Examples: AcrySof IQ ReSTOR SN6AD3, ReSTOR SN6AD1, ReSTOR SN60D3, ReZoom NXG1, Gradiol (concept-gradient refractive index optics), Mplus X, MS 714 PB Diff, Sulcoflex 653F, TECNIS ZM900, ZMA00 2. Implantation of 1 or 2 monofocal intraocular lenses with the aim of optimising near vision in 1 eye and distance vision in the other ('monovision') 3. Standard monofocal intraocular lenses with the same focal point in both eyes plus spectacles /contact lenses (optical correction) Examples: Akreos AO, ZA9003
Comparators	• All 3 listed interventions vs. each other • Different types of multifocal lenses vs. each other
Outcomes	• Unaided near, intermediate and distance visual acuity • Contrast sensitivity • Complications: glare and other optical aberrations • Visual function/Quality of life • Best corrected visual acuity (BCVA): near, intermediate and distance • Patient satisfaction • Resource use and costs

All RCTs involving either unilateral or bilateral implantation, comparing a multifocal IOL of any type with a monofocal IOL as control were included. Trials comparing multifocal IOLs with 'monovision', where 1 eye is optimised for distance vision and one eye optimised for near vision were also considered. Finally, trials of bifocal versus trifocal and diffractive versus refractive multifocal lenses were also included.

Papers were excluded if they:

- only examined accommodating multifocal lenses

- were narrative reviews, case studies/reports, commentaries, editorials/letters or opinion pieces
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies.

8.3.3 Evidence review

In the search undertaken by the Cochrane Eyes and Vision Group, 41 potentially relevant citations were retrieved for full-text screening, with 20 studies finally identified as meeting the inclusion criteria. For the full list of excluded studies, with reasons, see Appendix F.

8.3.3.1 Description of included studies

Details of the included studies can be found in Table 27, with full information given in the evidence tables (see Appendix E). Twenty RCTs were identified for inclusion in the Cochrane review, (Cillino 2008; ElMaghraby 1992; Haaskjold 1998; Harman 2008; Javitt 2000; Ji 2013; Jusufovic 2011; Kamlesh 2001; Labiris 2015; Leyland 2002; Nijkamp 2004; Palmer 2008; Peng 2012; Percival 1993; Rasp 2012; Rossetti 1994; Sen 2004; Steinert 1992; Wilkins 2013; Zhao 2010).

Table 27: Summary of included studies – multifocals vs monofocals and multifocals vs monovision

Study & location	Sample size	Methods
Cillino (2008) Italy	124 eyes	Comparison of new-generation multifocal intraocular lenses with monofocal lenses.
El Maghraby (1992) Saudi Arabia	61 eyes	Multifocal versus monofocal intraocular lenses. Visual and refractive comparisons.
Haaskjold (1998) Europe	221 eyes	Comparison of a diffractive bifocal and a monofocal intraocular lens. Contrast sensitivity after implantation of diffractive bifocal and monofocal intraocular lenses.
Harman (2008) England	86 eyes	Comparing the 1CU accommodative, multifocal, and monofocal intraocular lenses: a randomized trial.
Javitt (2000) USA, Germany, Austria	470 eyes	Cataract extraction with multifocal intraocular lens implantation: clinical functional, and quality-of-life outcomes: multicentre clinical trial in Germany and Austria. Cataract extraction with multifocal intraocular lens implantation. A multinational clinical trial evaluating clinical, functional, and quality-of-life outcomes.
Ji (2013) China	64 eyes	Visual performance of Acrysof ReSTOR compared with a monofocal intraocular lens following implantation in cataract surgery.
Jusufovic (2011) Bosnia and Herzegovina	100 eyes	Comparison of the binocular vision quality after implantation of monofocal and multifocal intraocular lenses.
Kamlesh (2001) India	40 eyes	Contrast sensitivity and depth of focus with aspheric multifocal versus conventional monofocal intraocular lens.
Labiris (2015) Greece	150 eyes	Mini-monovision versus multifocal intraocular lens implantation.
Leyland (2002) England	120 eyes	Prospective randomised double-masked trial of bilateral multifocal, bifocal or monofocal intraocular lenses.
Nijkamp (2004) Netherlands	274 eyes	Effectiveness of multifocal intraocular lenses to correct presbyopia after cataract surgery: a randomized controlled trial.

Study & location	Sample size	Methods
Palmer (2008) Spain	228 eyes	Visual function with bilateral implantation of monofocal and multifocal intraocular lenses: a prospective, randomized, controlled clinical trial.
Peng (2012) China	202 eyes	Optical performance after bilateral implantation of apodized aspheric diffractive multifocal intraocular lenses with +3.00-D addition power.
Percival (1993) England	50 eyes	Prospectively randomized trial comparing the pseudo-accommodation of the AMO ARRAY multifocal lens and a monofocal lens.
Rasp (2012) Austria	292 eyes	Bilateral reading performance of 4 multifocal intraocular lens models and a monofocal intraocular lens under bright lighting conditions.
Rossetti (1994) Italy	80 eyes	Performance of diffractive multifocal intraocular lenses in extracapsular cataract surgery.
Sen (2004) Finland	110 eyes	Quality of vision after AMO Array multifocal intraocular lens implantation. Journal of Cataract and Refractive Surgery
Steinert (1992) USA	62 eyes	A prospective, randomized, double-masked comparison of a zonal-progressive multifocal intraocular lens and a monofocal intraocular lens.
Wilkins (2013) England	374 eyes	Randomized trial of multifocal intraocular lenses versus monovision after bilateral cataract surgery.
Zhao (2010) China	161 eyes	Visual function after monocular implantation of apodized diffractive multifocal or single-piece monofocal intraocular lens randomized prospective comparison.

The original Cochrane review also conducted subgroup analyses looking for differences between unilateral and bilateral implantation of monofocal lenses, and differences between refractive and diffractive optics. No significant heterogeneity was found between these different groups, and therefore multifocal lenses are treated as a class in the analyses below.

The additional search undertaken by the NICE Internal Guidelines Team identified a further 177 potentially relevant references, of which 59 were ordered for full-text review. Of these, 56 were eventually excluded (see Appendix F for the full list of excluded studies, with reasons), with 3 additional RCTs included in the review. Details of the included studies can be found in Table 28, with full information given in the evidence tables (see Appendix E).

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

Table 28: Summary of included studies – bifocals vs trifocals and refractive vs diffractive multifocals

Study & location	Population	Methods
Gunderson (2016) Norway	22 people	Intra-person RCT of bifocal versus trifocal lens implantation
Junker (2015) Netherlands	28 people	Inter-person RCT of bilateral bifocal versus trifocal lens implantation
Xu (2014) China	621 people	Systematic review containing 8 RCTs comparing refractive with diffractive multifocal lenses

Network meta-analyses were conducted for all outcomes where sufficient relevant data were available. Two types of analysis were undertaken:

- A class-level analysis, comparing monofocal, monovision and multifocal lenses.
- An analysis subdividing the different types of multifocal lens, and then comparing monofocal, monovision, refractive multifocal and diffractive multifocal lenses.

8.3.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

One study (Dolders et al., 2004) initially appeared relevant but was excluded after detailed review. This Dutch study compared multifocal and standard monofocal IOLs in a prospective analysis and the authors tracked costs and patient reported utilities over the course of the trial. The study was primarily concerned with costs outside the NHS/PSS budget as an endpoint. Moreover, the statistical analyses of utility values, and the differences between values from different metrics obtained at different time points relative to surgery were poorly described and the methods used could not be replicated nor, therefore, be critically appraised. For all these reasons, the study was not judged to provide applicable and worthwhile evidence.

8.3.5 Evidence statements

8.3.5.1 Distance visual acuity

Very low- to low-quality evidence from 2 network meta-analyses containing up to 13 studies (1,395 participants) could not differentiate uncorrected distance visual acuity between monofocal, monovision and multifocal lenses at the class level, but found that refractive multifocal lenses had better outcomes than diffractive multifocal lenses.

Moderate-quality evidence from 6 RCTs containing 848 participants showed better corrected distance visual acuity in those given multifocal compared with monofocal lenses.

8.3.5.2 Intermediate visual acuity

Low- to moderate-quality evidence from 1 RCT containing 202 participants showed better uncorrected and corrected intermediate visual acuity in those given multifocal compared with monofocal lenses.

Moderate-quality evidence from 1 RCT containing 181 participants showed better uncorrected intermediate visual acuity in those given monovision versus multifocal lenses.

8.3.5.3 Near visual acuity

Low-quality evidence from 2 network meta-analyses containing up to 6 studies (1,015 participants) found multifocal lenses, as a class, gave better uncorrected near visual acuity than monofocal lenses, predominantly because of a benefit of diffractive multifocal lenses over monofocal lenses.

Low-quality evidence from 6 RCTs containing 1,003 participants could not differentiate corrected near visual acuity in people given multifocal compared with monofocal lenses.

8.3.5.4 Spectacle dependence

Low-quality evidence from 2 network meta-analyses containing up to 15 RCTs (1,466 participants) showed that people given monovision had higher spectacle dependence than people given either monofocal or multifocal lenses at the class level, with monofocal lenses

having higher spectacle dependence than multifocal lenses. People given refractive multifocal lenses had higher levels of spectacle dependence than people given diffractive multifocal lenses.

Low-quality evidence from up to 6 RCTs containing 772 people showed that those given multifocal lenses had lower levels of near spectacle dependence than people given monofocal lenses, but could not differentiate levels of distance spectacle dependence.

Low-quality evidence from 1 RCT of 75 people showed that people given multifocal lenses had lower levels of distance spectacle dependence than people given monovision, but could not differentiate levels of near spectacle dependence.

8.3.5.5 Contrast sensitivity

Moderate-quality evidence from 2 network meta-analyses containing up to 6 studies (550 people) showed that monovision and monofocal lenses gave better contrast sensitivity than diffractive multifocal lenses.

8.3.5.6 Visual function

Very low-quality evidence from up to 4 RCTs containing 480 people could not differentiate levels of visual function (measured using the VF-7 or VF-14) between multifocal lenses and either monovision or monofocal lenses.

8.3.5.7 Vision-related quality of life and patient satisfaction

Very-low to low-quality evidence from up to 6 RCTs containing 643 people could not differentiate levels of vision-related quality of life or patient satisfaction between those given multifocal or monofocal lenses.

8.3.5.8 Glare

Moderate-quality evidence from 2 network meta-analyses of 10 RCTs containing 845 people showed that multifocal lenses were associated with higher rates of glare than monovision or monofocal lenses, with refractive multifocal lenses associated with higher rates than diffractive multifocal lenses.

8.3.5.9 Halo

Moderate quality evidence from a network meta-analysis of 9 RCTs containing 776 participantsshowed that multifocal lenses are associated with higher rates of halo than monofocal lenses, with refractive multifocal lenses associated with higher rates than diffractive multifocal lenses.

8.3.5.10 Dysphotopsia

Low-quality evidence from 1 RCT containing 86 participants could not differentiate rates of dysphotopsia between people given multifocal or monofocal lenses.

8.3.5.11 Health Economics

No health economic evidence was identified for this review question.

8.3.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that there were a range of relevant outcomes for this review, including both corrected and uncorrected near, intermediate and distance visual acuity, spectacle independence, contrast sensitivity, glare and other optical aberrations. It agreed that these trade-offs would be best assessed through measures that synthesised both the benefits and harms of the lenses, which would include visual function, quality of life and patient satisfaction.
Trade-off between benefits and harms	The committee agreed that there was evidence that multifocal IOLs showed a greater benefit in terms of uncorrected visual acuity and spectacle independence than monofocal lenses, although it noted that multifocal lenses were associated with higher rates of glare and halos. It also agreed that the evidence showed that diffractive multifocal lenses were of greater benefit than refractive lenses, and had less adverse events. The committee stated that the higher absolute rates of glare with more recent studies could be due to modern multifocal lenses being more susceptible, or that the patients in the studies were asked to report glare in different ways over time – that is, any effects would have been spontaneously reported in early studies but more carefully elicited as time progressed in the later ones. The committee stated that the very small advantage in best corrected visual acuity for monofocal lenses could be explained by the lack of compromise in optics with only one focal point. The committee agreed that it did not find the uncorrected visual acuity finding surprising and that no difference in visual function being found between multifocal and monofocal lenses suggests that the benefits and harms may cancel each other to some degree. It discussed the trend in the evidence of patients reporting less spectacle dependence with multifocal lenses, stating that this could be due to how people feel about some loss of distance vision if they do not need spectacles for near vision. Committee members also raised concerns as to bias with regards to patient satisfaction for spectacle dependence (especially distance) in how the questions were phrased. Overall, the committee did not feel these was evidence of compelling clinical benefits in favour of either multifocal or monofocal lenses. It was agreed the loss of intermediate visual acuity may be particularly troublesome for younger patients. Group members suggested that that older patients will have adapted to a gradual loss of intermediate vision over time (varifocal spectacles can address this, but the committee agreed that there was some variation in practice for offering these). The committee agreed that, in practice, monovision is optimised for intermediate and distance vision rather than near and distance vision as patients will not tolerate too big a difference between both eyes. It highlighted that 1 of the studies of monovision aimed for slight myopia in both eyes, and so it was unsurprising that people with monovision in this study reported high levels of spectacle dependence. Even when monovision aims for emmetropia in 1 eye, people often require spectacles for driving in order to correct their myopic eye. The committee noted that it would like to see more research undertaken in the area of monovision within different populations; in particular, the degree of anisometropia should be studied in order to identify an optimal difference.
Consideration of health benefits and resource use	The committee noted that the benefits shown by multifocal lenses, compared with monofocal lenses were in uncorrected visual acuity and spectacle independence. The committee discussed the often expressed desire by people to be spectacle-free following their

	surgery, but felt that the likely QALY gains of spectacle independence would be extremely small. Consequently, the committee did not feel that the known additional costs of multifocal lenses could be justified by the benefits observed, and therefore felt it was appropriate to make a "do not offer" recommendations for their routine use. The committee reported that, in its experience, multifocal lenses are many times the cost of monofocal lenses and thus their adoption could have a substantial resource impact. The committee was made aware of the presence of a diffractive, square-edged multifocal lens in the NHS purchasing catalogue at a price comparable to that of monofocal lenses. It was agreed that this was likely to represent an older lens type and one that would therefore not be used in clinical practice. Group members were not familiar with this particular lens (or its manufacturer) and, without having any direct experience, the committee was not happy to assume that the lens is generally available, nor that it would provide similar results to those used in the RCTs under review. The committee agreed that it was not only the individual cost of the lens that was the issue, but rather the cost of the care pathway within the NHS. They agreed that this would be substantial in terms of cost and resources, highlighting the current 10% chance of needing a lens explantation with multifocal lenses.
Quality of evidence	The committee discussed the evidence presented and agreed that, although there were gains in uncorrected visual acuity in multifocal lenses, the increase in risk of glare and halos also has to be considered. It agreed that overall the benefits demonstrated in the RCTs were only seen in particular patient groups, as the trials excluded potential participants such as professional drivers or people with an unrealistic expectation of improved outcomes from any such implantation. For these reasons, the committee concluded that, even before cost is taken into account, it would not be appropriate to offer multifocal lenses routinely. The committee agreed that all the studies presented had a risk of bias as they were not fully masked, and thus the evidence was reduced in quality. The committee raised concerns that the tests used in the studies were not sensitive enough to determine the quality of life outcomes, and also that the newer generation of multifocals have improved over time and a historical trend in outcome improvements could be noted. The committee noted very few trends in either benefit or harm within the evidence presented for monovision, although it agreed that monovision gave the poorest distance spectacle dependence outcome. It stated that within current practice it was usual to aim for monovision in patients who naturally have anisometropia, and agreed it was appropriate to make a recommendation that people who have preoperative anisometropia or have had a successful contact lens trial, and express a desire to remain that way after surgery, should be offered postoperative monovision.
Other considerations	The committee agreed that it was not possible to make different recommendations on multifocal lenses for people with high levels of preoperative astigmatism compared to those without, as the RCTs either routinely excluded this patient population, or did not report results separately for the subpopulation with preoperative astigmatism. Therefore, it was agreed to be appropriate to make a research recommendation to evaluate the effectiveness of multifocal lenses in this group.

8.3.7 Recommendations

23. Do not offer multifocal intraocular lenses for people having cataract surgery.

24. **Offer monovision after cataract surgery to people who:**
    - are already using monovision **or**
    - have had a successful contact lens trial before cataract surgery.

8.3.8 Research recommendations

10. **What is the effectiveness of different approaches to monovision (the degree of anisometropia) versus standard monofocal lenses?**

Why is this important?

The current evidence indicates that the approaches to monovision that have been tested in clinical studies do not give good outcomes for either distance vision or spectacle dependence, with current practice being to offer monovision in people who naturally have anisometropia. However, there are other approaches to monovision that may provide better outcomes, particularly in being able to simultaneously optimise for near and distance vision. Well conducted research to determine the effectiveness of postoperative monovision against the use of standard monofocal lenses would help to inform future recommendations for cataract surgery.

8.4 Optimal strategy to address pre-existing astigmatism

8.4.1 Review question

- What is the optimal strategy to address pre-existing regular astigmatism in people undergoing cataract surgery?

8.4.2 Introduction

The aim of this review was to determine the optimal strategy to address pre-existing astigmatism in people undergoing cataract surgery. The review focused on identifying studies that fulfilled the conditions specified in Table 29. For full details of the review protocol, see Appendix C.

Table 29 PICO inclusion criteria for astigmatism

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery with intraocular lens implantation with pre-existing astigmatism
Interventions	• Corneal (limbal) relaxing incisions • On-axis surgery (incision is made on steepest axis to flatten it) • Astigmatic keratotomy • Opposite clear corneal incisions (OCCI) • Toric intraocular lens
Outcomes	• Visual acuity • Level of astigmatism • Patient satisfaction • Quality of life • Resource use and cost (including time taken)

Papers were excluded if they:

- were narrative reviews, case studies/reports, commentaries, editorials/letters or opinion pieces
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- reported studies conducted entirely in non-OECD countries
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

8.4.3 Evidence review

In total, 688 references were found from a database search for the review question, and full-text versions of 57 citations that seemed potentially relevant to this topic were retrieved and screened at full-text. One systematic review (Kessel et al., 2016) reporting 7 RCTs was identified, to which 4 randomised controlled trials identified in the search were added (Emesz et al., 2015; Kaufmann et al., 2016; Leon et al., 2015 and Ouchi et al., 2010).

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

8.4.3.1 Description of included studies

The design of included studies is summarised in Table 30. Full details and results are found in the evidence tables (see Appendix E).

Table 30 Summary of included studies – astigmatism

Study & location	Population	Methods
Emesz (2015) Austria	39 patients (78 eyes)	RCT comparing low, moderate and high toric value lenses with a non toric lens in cataract patients with astigmatism.
Gangwani (2014) UK	58 eyes	RCT comparing multifocal toric lenses with multifocal non-toric accompanied with peripheral corneal relaxing incisions. Citation found within Kessel (2016) Systematic Review
Hirnschall (2014) UK	30 patients (60 eyes)	RCT comparing the astigmatism-reducing effect of a toric intraocular lens and peripheral corneal relaxing incisions. Citation found within Kessel (2016) Systematic Review
Kessel (2016) USA	13 RCT studies	Systematic review comparing toric and non-toric IOL's to correct astigmatism during cataract surgery.
Kaufmann (2005)	71 eyes	RCT to compare limbal relaxing incisions with placement of the corneal cataract incision on the steepest keratometric axis to reduce pre-existing astigmatism at the time of cataract surgery
Leon (2015) Italy	102 eyes (102 patients)	RCT comparing toric and monofocal lenses with limbal relaxing incisions to manage low corneal astigmatism in cataract surgery.
Maedel (2014) Austria	39 eyes	RCT to compare the astigmatism-reducing effect of an aspheric toric IOL and an aspheric non-toric IOL with an opposite clear corneal incision in cataract surgery. Citation found within Kessel (2016) Systematic Review
Mendicute (2009) Spain	40 eyes	RCT to compare toric IOL implantation with paired opposite clear corneal incisions for astigmatism correction in patients having cataract surgery. Citation found within Kessel (2016) Systematic Review
Mingo-Botin (2010) Spain	40 eyes	RCT to compare toric and spherical IOL implantation with peripheral corneal relaxing incisions to manage astigmatism during phacoemulsification. Citation found within Kessel (2016) Systematic Review
Ouchi (2010)	189 eyes	RCT to evaluate the outcomes of limbal relaxing incisions combined with bimanual phacoemulsification and insertion of an intraocular lens.
Visser (2014) Netherlands	86 patients (172 eyes)	RCT comparison of toric vs aspherical control lenses in cataract patients with astigmatism. Citation found within Kessel (2016) Systematic Review
Waltz (2015) USA	197 patients (433 eyes)	RCT to evaluate toric vs non-toric IOL's in patients with corneal astigmatism undergoing cataract surgery. Citation found within Kessel (2016) Systematic Review

8.4.4 Health economic evidence

8.4.5 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references were retrieved, of which 1 was retained for this review question. Health economic modelling was not prioritised for this review question.

Pineda (2010) developed a decision-analytic model which examined the costs and outcomes among patients 65 years and older with cataract and pre-existing astigmatism (1.5–3.0 dioptres) who were allocated to either toric or conventional IOLs with and without

intraoperative refractive correction (IRC). Data were obtained from a literature review of effectiveness studies, and a survey of ophthalmologists (n=60) conducted online in May 2008. For each treatment option, ophthalmologists indicated the percentage of patients who would normally not need visual aids for distance vision following cataract treatment. They also indicated the percentage of these patients whose uncorrected visual acuity would be 20/25 or better, worse than 20/25 to 20/40, and worse than 20/40 OU.

Surgeons also reported the percentage of patients who would require further intervention to achieve optimal distance vision and the proportion of them with less than 1.0 D and 1.0 D or more of residual refractive cylinder after cataract treatment. They also indicated the percentage of these patients who would receive nonsurgical (spectacles or contact lenses) and surgical (laser vision correction, incision corneal surgery, or conductive keratoplasty) interventions for each refractive cylinder group.

The respondents reported rates of retreatment (second refractive surgery) to optimise vision, use of different re-treatment options, and the mean time between cataract and follow-up refractive surgery. In addition, the ophthalmologists indicated the percentage of their patients receiving spectacles or contact lenses and undergoing refractive surgery among the 3 UCVA groups mentioned previously.

Patient utilities were based on data from a prospective study using the time trade-off and standard gamble methods among patients with various vitreoretinal diseases. Utility weights were calculated by converting the UCVA levels into Snellen decimal values (a midpoint was obtained for the level of 20/25 to 20/40 OU) and applying an equation derived by Brown et al. 2000 (Utility = 0.37 × UCVA + 0.514). Each additional year after surgery was weighted by these utility values to derive quality-adjusted life years (QALYs), which were summed during 18 years and annually discounted by 3% to compute cumulative lifetime estimates.

Table 31 Economic results

Base-case Results						
	First Year			**Lifetime**		
	Incremental Cost of Treatment	Incremental Cost per Patient With UCVA of 20/40 or Better OU	ICER	Incremental Cost of Treatment	Incremental Cost per Patient With UCVA of 20/40 or Better OU	ICER
Toric IOL						
Patient costs	$1,052	$12,074	$141,282	$-34	$-393	$-349
Total costs	$1,080	$12,406	$145,165	$-5	$-61	$-54
Standard monofocal IOL with intraoperative LRI/PCRI						
Patient Costs	$947	$22,852	$299,650	$160	$3,866	$3,851
Total Costs	$968	$23,346	$306,141	$181	$4,361	$4,344

Disaggregated and total QALYs are not reported in the text. The base-case results suggest that incremental cost differences in treatment terms are small, and that over a lifetime horizon the use of toric IOLs generates a small saving in terms of patient and provider borne

costs. A best-case and worst-case sensitivity analysis suggests that at both a lower cost of the toric IOL and higher spectacle independence rate (best-case scenario), toric IOLs remained a more expensive option in the first year compared with conventional IOLs without IRC. However, modification of either or both of these measures resulted in greater incremental lifetime savings compared with base-case measures. Conversely, at both a higher toric IOL cost and a lower spectacle independence rate (worse-case scenarios), the toric IOL became the more expensive option during the patient's lifetime. The toric IOL was not a cost-saving option across the patient's lifetime if the frequency of changing spectacles was reduced to once every 3 years. Similar patterns of sensitivity were evident in the subgroup analysis.

8.4.6 Evidence statements

8.4.6.1 Toric IOL versus non-toric IOL

8.4.6.1.1 Visual acuity (uncorrected distance)

High-quality evidence from 10 RCTs containing 773 eyes found that people who received a toric intraocular lens had better uncorrected distance visual acuity than those who received a non-toric intraocular lens (with or without limbal relaxing incisions).

8.4.6.1.2 Visual acuity (corrected distance)

Moderate-quality evidence from 2 RCTs containing 250 eyes could not differentiate corrected distance visual acuity between people receiving a toric or a non-toric intraocular lens.

8.4.6.1.3 Residual astigmatism – refractive cylinder dioptres

High-quality evidence from 9 RCTs containing 781 eyes found that people who received a toric intraocular lens had lower levels of postoperative astigmatism than those who received a non-toric intraocular lens (with or without limbal relaxing incisions).

8.4.6.1.4 Spectacle independence for distance viewing

High-quality evidence from 6 RCTs containing 867 eyes found that people who received a toric lens had less spectacle dependence for distance viewing than those who received a non toric lens (with or without limbal relaxing incisions).

8.4.6.2 Limbal relaxing incisions versus no limbal relaxing incisions

8.4.6.2.1 Visual acuity (uncorrected distance)

High-quality evidence from 1 RCT containing 189 eyes found that people who received limbal relaxing incisions had better uncorrected distance visual acuity than those who received no limbal relaxing incisions during cataract surgery.

8.4.6.2.2 Visual acuity (corrected distance)

Moderate-quality evidence from 1 RCT containing 189 eyes could not differentiate corrected distance visual acuity between people receiving limbal relaxing incisions versus no limbal relaxing incisions during cataract surgery.

8.4.6.2.3 Residual astigmatism – refractive cylinder dioptres

High-quality evidence from 1 RCT containing 189 eyes found that people who received limbal relaxation incisions had lower levels of postoperative astigmatism than those who received no limbal relaxation incisions during cataract surgery.

8.4.6.3 Limbal relaxing incisions vs on-axis incisions

8.4.6.3.1 Residual astigmatism – refractive cylinder dioptres

Low-quality evidence from 1 RCT containing 71 eyes could not detect a difference in levels of postoperative astigmatism between people receiving limbal relaxing incisions versus on-axis incisions during cataract surgery.

8.4.6.4 Health economic evidence

1 partly applicable study with serious limitations suggests that toric IOLs may reduce lifetime patient borne costs by reducing the need for spectacles or contact lenses following cataract removal.

8.4.7 Evidence to recommendations

Relative value of different outcomes	The committee stated that improvements in quality of life, visual outcomes, reduced residual astigmatism or a reduced need for spectacles after cataract surgery would all be relevant outcomes. For measures of visual outcomes or level of astigmatism, it was agreed that the evidence would be stronger if it was able to demonstrate what level of overall benefit in quality of life an individual would, on average, receive from an improvement in these clinical measures.
Trade-off between benefits and harms	The committee agreed that there was evidence to suggest a clinical difference in improving uncorrected visual acuity, reducing residual astigmatism and reduced use of spectacles between using toric and non-toric lenses. However, there was no evidence to demonstrate what impact these changes would have on the overall quality of life of an individual, particularly when no differences were found in corrected visual acuity. Similarly, a clinical benefit was demonstrated for limbal relaxing incisions and, by extension, on-axis surgery (as no difference could be found between limbal relaxing incisions and on-axis surgery)
Consideration of health benefits and resource use	The committee reviewed one cost–utility analysis from the USA but agreed that it was not possible to relate the costs used in that analysis to the NHS perspective. The committee agreed that, in practice, the acquisition cost of toric lenses is unlikely to exceed that of standard monofocal lenses by a significant margin. However, it had significant concerns about the increased resource burden that would be incurred by the NHS should toric lenses be recommended. This could include the need for an additional preoperative appointment, additional biometry to measure corneal topography (not available in all centres) and additional minutes of surgical time (committee estimated 5+ extra minutes). There would also be an additional cost for surgical equipment (toric markers for example). The committee also discussed the need for more follow-up appointments in patients given toric lenses to check refractive correction, and the need to account for the poor visual satisfaction in patients who may not be able to get a toric lens in both eyes. Surgical members of the committee also raised concerns that implanting toric lenses could increase the likelihood of intraoperative complications because of the additional complexity of the procedure, and this also had implications for staff training. The committee emphasised that none of these parameters were included in the cost-utility analysis presented. The committee concluded that the relative benefit in UCVA from toric lenses shown by the evidence (which was not matched by evidence of relative BCVA gains) was not sufficiently robust evidence to justify the trade-off in increased resource use. The committee discussed the often expressed desire by people to be spectacle-free following their surgery, but felt that the likely QALY gains of spectacle independence

	would be extremely small, and many people would still require spectacles for reading as is the case for people without astigmatism undergoing cataract surgery. In the final analysis, the committee reflected that, in the absence of clear advantage in quality of life over standard monofocal lenses, toric lenses are unlikely to represent a cost effective treatment option for patients with astigmatism compared with standard monofocal lenses. The committee agreed that further research was needed looking at the cost effectiveness of toric lenses within an NHS context and in the use of limbal relaxing incisions during cataract surgery. The committee noted there were no such resource constraints for either limbal relaxing incisions or on-axis surgery, and therefore felt it reasonable to make a 'consider' recommendation for both these aspects of surgical technique.
Quality of evidence	The committee noted that, although the evidence presented was moderate in quality, the studies will have been undertaken by surgeons with a great deal of experience in using toric lenses. It also commented on the high number of studies that were sponsored by toric lens manufacturing companies. It agreed that, although the exclusion criteria in the trials seemed extensive, they were reasonable and unlikely to impact on the overall pattern of the evidence.
Other considerations	The committee discussed whether it would be appropriate to make a 'do not do' recommendation with regard to toric lenses (as it had for multifocal lenses). It noted that, whereas it had seen evidence of adverse outcomes with multifocal lenses, there were no such concerns for toric lenses. The committee agreed that – although current evidence does not support their use – it is not implausible that toric lenses could provide benefit at a cost the NHS would consider reasonable (this possibility motivated its research recommendation on the subject). For these reasons, the committee agreed that it should not explicitly recommend against toric lenses, but should confine itself to making a positive recommendation about alternative strategies.

8.4.8 Recommendations

25. Consider on-axis surgery or limbal-relaxing incisions to reduce postoperative astigmatism.

8.4.9 Research recommendations

11. What is the cost effectiveness of toric lenses compared with on-axis or limbal-relaxing incision surgery, or non-toric lenses with no further intervention, in an NHS context, taking account of the whole care pathway cost implications from pre- to postoperative phases, stratified by the preoperative level of astigmatism?

Why this is important

There is clear evidence that toric lenses are effective at reducing levels of postoperative astigmatism, but evidence on their cost effectiveness is much less conclusive. Although a cost–utility analysis of toric lenses was evidenced from the USA, it was not possible to relate the costs to a UK NHS perspective. Acquisition costs of toric lenses are unlikely to exceed those of standard monofocal lenses, but their use has possible associated costs, including additional preoperative tests, biometry measurements, surgical time and equipment (toric markers), postoperative assessments and further surgery, which could be significant. A comparison with on-axis or limbal-relaxing incisions would be advantageous because there

are currently no resource constraints for using these techniques. Further cost-effectiveness research using UK NHS costings would be of benefit in helping to formulate future recommendations about their use.

12. What is the effectiveness and cost effectiveness of limbal relaxing incisions (in combination with any intraocular lens type) to reduce postoperative astigmatism?

A limited evidence base was identified on limbal relaxing incisions in combination with monofocal intraocular lenses as a technique to reduce postoperative astigmatism, and the committee made a consider recommendation based on this evidence. However, additional studies, either adding to this evidence base or considering limbal relaxing incisions in combination with other types of intraocular lens would help to strengthen the evidence base in this area and guide future recommendations.

9 Wrong lens implant errors

Although infrequent, one of the most prevalent confusions and potentially preventable errors during cataract surgery remains the insertion of an incorrect or wrong intraocular lens (IOL) implant. When unrecognised intraoperatively these IOL implantation errors result in 'refractive surprise', wherein an unexpected/unintended postoperative refractive outcome occurs (Zamir et al., 2012).

Implantation of an incorrect IOL leading to unplanned refractive error is one of the most frequent causes of litigation in ophthalmic care and is classified by the NHS as a 'never event' (Kelly et al., 2012). Despite this, of the 442 NHS 'never events' reported for the 1 year period between 1st April 2015 and 31st March 2016, 26 (5.9%) were due to wrong lens implantation (NHS England Never Events report).

Unfortunately, these errors may occur at any stage from the decision to operate to the insertion of the IOL, but they are almost universally due to a breakdown in the safety protocols designed to prevent surgical confusion, rather than to a primary cognitive misjudgement. Because these errors may be introduced at multiple different time points throughout the cataract pathway, strict protocols, which encompass all elements of the patient's journey, will be necessary to abolish these preventable problems.

However, by careful introduction of, and rigid adherence to, suitable safety standards and protocols, it should be possible for these system errors to be largely eliminated from current ophthalmic practice.

9.1 Wrong lens implant errors

9.1.1 Review questions

- What are the procedural causes of wrong lens implant errors?
- What strategies should be adopted to reduce the risk of wrong lens implant errors?

9.1.2 Introduction

The aim of this review was to determine the procedural causes of wrong lens implant errors and strategies that help to reduce the risk of these events from occurring.

The qualitative review focused on identifying studies that fulfilled the conditions specified in Table 32. For full details of the review protocols, see Appendix C. The main outcomes for these review questions were procedural causes of wrong lens implant errors and error rates to assess the effectiveness of strategies to minimise the risk of occurrence of these events. Although these were 2 separate review questions, all of the identified evidence overlapped both topics.

Table 32: PICO inclusion criteria for the review questions on wrong lens implant errors

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery with intraocular lens implantation
Factors/ Interventions	• Factors that result in wrong lens implant errors • Strategies to minimise risk of wrong lens implant errors e.g. surgical checklists
Outcomes	• Procedural causes of wrong lens implant errors • Wrong lens implant error rates • Resource use and cost

Papers were excluded if they:

- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- were not published in the English language

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

9.1.3 Evidence review

In total, 3,395 references were found for this review question and full-text versions of 35 citations that seemed potentially relevant to the topic were retrieved. These included a mixture of registry audits, narrative reviews, editorials, letters/commentaries and case reports. All citations were appraised for relevance against the inclusion criteria in the review protocols and in terms of providing rich qualitative information (as defined by the CERQual methodology detailed in Lewin et al., 2015) on the causes of wrong lens implant errors and strategies to reduce the risk of such events. Papers were prioritised on the basis of richness of content in terms of depth and volume, and relevance to the UK setting. Four key papers were identified (Kelly and Jalil, 2011; Kelly et al., 2013; Schein et al., 2012; Zamir et al., 2012). The remaining papers were appraised to identify any new additional information not already included in these 4 key papers. An additional relevant paper was identified via an editorial and included (Kelly and Astbury, 2006), and a further additional paper was identified from the rerun searches conducted at the end of the guideline (Steeples et al., 2016).

The included studies contained quite different methodological approaches and data sources. Kelly and Astbury (2006) designed a thematic analysis of narratives collected at a focus group meeting of clinicians in the UK. Kelly and Jalil (2015) and Steeples (2016) reviewed all

intraocular lens (IOL) related incidents reported in the England and Wales National Patient Safety Agency (NPSA) National Reporting and Learning System database (NRLS) and conducted a thematic qualitative analysis of the event types and causes. Kelly et al. (2013) surveyed members of the Royal College of Ophthalmologists to ascertain the extent of surgical checklist use and their design characteristics. In a US study of 7 IOL implant error case studies, Schein et al. (2012) presented the narrative data collected during a root-cause analysis (RCA) of wrong lens implant errors and possible strategies to reduce their occurrence were derived from the RCA themes. Finally, Zamir (2012) qualitatively described the implementation of a specific protocol to reduce wrong lens errors.

Details of the included studies are provided in Appendix E.

A thematic content analysis (Lewin et al., 2015) of the identified papers was undertaken to determine the procedural causes of wrong lens implant errors and suggestions of strategies or tested methods to minimise the risk of such events from occurring. The evidence was assessed using the CERQual methodology (Appendix G).

9.1.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references were retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

9.1.5 Evidence statements

9.1.5.1 Procedural causes of wrong lens implant errors

Evidence from 4 studies indicated that wrong lens implant errors may be attributed to (moderate-confidence evidence base):

- Poor patient–provider communication (leading to mismatches between the preferences of the patient and the target of the surgeon with regard to refractive outcome)
- Errors in preoperative biometry assessment (measurement, calculation and data entry errors)
- Poor record/document management (misplacement of biometry results in wrong patient records, confusion among multiple biometry results, transcription errors, illegible handwriting and use of unclear signs/abbreviations)
- Poor pre-surgical planning/checking (out of stock or wrongly ordered IOLs e.g. negative or positive dioptre, anterior or posterior chamber)
- Inadequate patient preparation/checks (lack of confirmation from records of correct eye, no marking of the surgical eye, patients mistakenly indicate wrong eye when asked by healthcare professionals)
- Poor theatre team communication (non- or partially updated surgical lists/whiteboards, lack of correct patient identification and confirmation, assumption that other team members are aware of issues)
- Poor or inconsistent handling of IOLs (unclear or mislabelled IOLs at manufacturer and user levels, inconsistent placement of patient selected IOL in operating theatre, multiple IOLs in operating theatre simultaneously)
- Poor management of intraoperative complications, which may require an alteration to the surgical plan and a different lens, at which time an additional opportunity for incorrect lens insertion arises
- Lack of adherence to standard operating procedures/checklists/protocols or unavailability of such policy documents (time pressures, busy theatre list, new staff/staff turnover and training)

- Lack of systems/culture/environment to facilitate open reporting, learning from near misses and critical incidents and implementation of solutions (multidisciplinary evaluation of incidents to undertake root-cause analysis of patient safety incidents)

9.1.5.2 Strategies to reduce the risk of wrong lens implant errors

Evidence from 4 studies suggested the following strategies could minimise the risk of occurrence of wrong lens implant errors (moderate-confidence evidence base):

- Comprehensive, documented patient–provider communication (including a documented surgical plan, with refractive target and IOL type discussed with the patient)
- Confirmation of preoperative biometry assessment (use of original printouts or automatically uploaded electronic systems, checking measurements and calculations with multiple members of the surgical team, and the use of best practice guidelines in undertaking calculations)
- Improved record/document management (including cross-checking 2 patient identification variables – for example, full name, hospital number, address, date of birth)
- Improved theatre team communication (including confirmation of biometry from original results rather than surgical lists/whiteboards)
- Pre-surgical checklists/standard operating procedures
- Use of surgical 'time-out' immediately before operation to confirm with the theatre team that the correct patient and correct IOL implant are present, and the correct procedure is to be undertaken in the correct eye

9.1.5.3 Health Economic Evidence

No health economic evidence was identified for this review question.

-

9.1.6 Evidence to recommendations

Relative value of different outcomes	The main outcomes of interest were narrative descriptions of the procedural causes of wrong lens implant errors, and strategies that could be recommended to prevent their occurrence.
Trade-off between benefits and harms	The qualitative review identified several commonalities in the evidence with regard to the procedural causes of wrong lens implant errors. These ranged from problems of communication between staff, and between staff and patients, to technical considerations such as data-input errors or calculation problems, to organisational/logistical causes such as problems with lens stocks and surgical list management. The committee noted that the emerging themes from the evidence tallied with their own learning about such events, and the clinical expert's introduction to the topic given prior to the evidence presentation. The committee considered that all of the strategies emerging from the thematic analysis were beneficial, with very little potential trade-off with harm. The committee did note that the use of surgical lists had value, but were keen to emphasise that generic checklists (such as the WHO pre-surgical checklist) should be customised to fit the context of cataract surgery, and cautioned that such checklists should not become a box-ticking exercise but should be regarded as an integral part of the surgical procedure. The committee recognised that surgical checklists add to the time taken to perform the surgery, and may therefore have some impact on throughput, but that this was far outweighed by their overall benefit and that indirect evidence from non-cataract surgeries demonstrates that surgical checklists reduce

	adverse outcomes. With fewer errors, and better outcomes, checklists become a net benefit to throughput, and not a hindrance. The committee was aware of the NPSA cataract surgery checklist, but felt that it lacked some important items (no requirement for more than 1 of the selected lens to be in stock in case of defects/problems with the first one used; no matching of patient, notes and biometry reports) which precluded them from recommending it outright. Instead, the committee chose to highlight important items that should be on a cataract-surgery-specific checklist, without making a specific recommendation for a particular checklist. There was inconsistency in the evidence about the timing of surgical checklist administration, and the committee felt that this consideration should take into account the type of anaesthesia used – noting that it would be inappropriate to administer a checklist (which may contain items requiring an abort of surgery) after the administration of general anaesthesia. The committee agreed it was important for the development of the surgical plan to involve a discussion with the patient about the refractive implications of lens selection and implantation (also considered in the section of this guideline on patient information). The patient preferences should be captured at the time of this discussion and inserted into the patient notes. The committee placed emphasis on the timing of the capture of this information, and were of the opinion that errors and subsequent patient dissatisfaction with outcome are more likely to occur if there is a delay between the consultation with the patient and the recording of their stated preferences. The committee agreed that it was important to use 2 identifiers to confirm a patient's identity and match them to the correct notes and biometry documentation. However, rare instances from committee members' own experience indicated that this may not be sufficient in all cases, for example when two patients have very similar names and share a date of birth. For this reason, the committee felt that the patient's address was a useful additional 3rd identifier, closer to being truly 'unique', and one that was readily available whereas others, for example hospital number would possibly not be known by the patient. Transcription errors were a recurrent theme in the literature review, and the committee felt that transcription should be avoided wherever possible and original biometry printouts should become the standard point of reference. The committee noted that in some instances there was a need to transpose data into ultrasound biometry equipment where A-Scan biometry was needed, but that errors could be minimised by again ensuring that the source of input data was checked, matched with information in the patient notes, and that important numerical data were clearly highlighted and consistently labelled. The committee felt it was important that biometry reports should not be inserted loosely into patient notes but fixed securely, to minimise the risk of loss or transposition. The committee emphasised that patient notes must be available on the day of surgery. If notes are unavailable, this would be cause to direct-abort the planned procedure until the notes are found. In the case of missing biometry only, it may be possible to re-measure on the same day as the procedure and continue as planned.
Consideration of health benefits and resource use	No health economic evidence was found for this review question, and it was not prioritised for de novo modelling work. The committee did not consider the recommendations made would have significant resource implications.

Quality of evidence	The overall quality of evidence was graded as moderate. The thematic analysis was based on relatively few studies, although coherence between these studies was good throughout. Most evidence was from NHS or US hospital settings, and had high relevance and adequacy with the exception of two studies based on a small UK focus group and a US case series of 7 events. Even though these studies were limited in terms of sample size the committee felt that the issues raised were relevant and congruent with the other evidence.
Other considerations	The committee emphasised in their discussions that a common theme in the evidence was the systematic nature of errors leading to wrong lens implant error. The name of the event implies that the error occurs at the point of implantation, but in fact clinicians may be operating in good faith that the lens is correct for the patient. The error may have occurred much earlier, at the point of biometry report transcription, or during the consultation with the patient about refractive outcomes. Strategies to limit the occurrence of IOL implant errors should therefore be implemented at all stages of patient contact and before and during the surgical procedure using a systematic approach. The committee emphasised that an important distinction should be made between circumstances where imperfect biometry calculation leads to an incorrect lens implanted in good faith, which should not be classed as a 'never event', and the circumstances in which procedural failure (for example, incorrect transcription of data) results in an IOL implant error, which would be classed as a 'never event'. The committee also highlighted the current ambiguity with regard to mandatory reporting of root-cause analysis at the national level, which should occur in order to facilitate a shared 'lessons learned' approach at a wider scale than individual trusts. Whilst acknowledging that this evidence review was primarily concerned with 'never events' the committee drew attention to and sought to encourage the use of the CORESS confidential incident report database which has a remit to record and reduce near-misses, from which learning may also be gained. The forthcoming National Cataract Registry dataset will also include an opportunity to document surgical complications including IOL implant errors. The committee agreed that it was important that a root-cause analysis always be undertaken after any never event, in order to ensure procedures are put in place to prevent it from occurring again.

9.1.7 Recommendations

Before cataract surgery

26. Before the preoperative biometry assessment, ensure that the person's correct medical notes are used by confirming the person's:

- name
- address **and**
- date of birth.

27. Immediately after the preoperative biometry assessment:

- securely fix the printed biometry results to the person's medical notes
- check that the results include the person's name, address, date of birth and hospital number

- use electronic data transfer if uploading the results to an electronic health record
- do not transcribe the results by hand.

28. At the preoperative assessment:

- discuss the refractive implications of different intraocular lenses with the person
- base the choice of intraocular lens on the person's chosen refractive outcome
- record the discussion and the person's choices in their medical notes.

On the day of cataract surgery

29. The person's medical notes, including printed biometry results, must be available in theatre on the day of the cataract surgery.

30. Use a checklist based on the World Health Organization (WHO) surgical safety checklist, modified to include the following cataract surgery checks, to ensure that:

- the person's identity has been confirmed and matches information in:
  - the consent form
  - the printed biometry results **and**
  - the person's medical notes
- the eye to be operated on has been checked and clearly marked
- there is only 1 intraocular lens in the theatre, that matches the person's selected lens type and prescription
- at least 1 additional identical intraocular lens is in stock
- alternative intraocular lenses are in stock in case the selected lens needs to be changed if there are complications during surgery
- at least 2 members of the team, including the surgeon, have checked the appropriateness, accuracy and consistency of all:
  - formulas
  - calculations **and**
  - intraocular lens constants.

31. Before giving the person anaesthetic, ensure that:

- there is only 1 intraocular lens in the theatre, that matches the person's selected lens type and prescription
- at least 1 additional identical intraocular lens is in stock
- alternative intraocular lenses are in stock in case the selected lens needs to be changed if there are complications during surgery.

32. Immediately before the operation, the surgeon should:

- confirm the person's identity and ensure that the correct medical notes are being used, especially if using electronic patient records
- refer to the printed biometry results, not to transcribed information in the person's medical notes

- refer to the person's medical notes to check which refractive outcome they preferred
- verify that the correct intraocular lens has been selected and is available in theatre.

Occurrence of wrong lens implant errors

33. If a wrong lens is implanted, refer to NHS England's Never Events policy, and together with the whole multidisciplinary team:

- undertake a root-cause analysis to determine the reasons for the incident
- establish strategies and implementation tools to stop it from happening again.

10 Surgical timing and technique

10.1 Laser-assisted cataract surgery

Femtosecond lasers have been used to perform several stages of phacoemulsification cataract surgery since 2009 (Nagy et al., 2009). Laser generated pulses of highly focused infrared light (wavelength 1053nm) cut by creating localised cavitation bubbles within tissues, a process termed photo-disruption. The ultrashort duration of each pulse (10-15 femtoseconds) minimises damage to adjacent tissue. During cataract surgery, such lasers are used to create incisions, perform capsulorhexis, and fragment the lens. The procedure is then completed using conventional phacoemulsification equipment and techniques.

Potential advantages of laser-assisted cataract surgery over conventional phacoemulsification cataract surgery include:

- Reproducible incisions including, where necessary, additional incisions to reduce postoperative astigmatism
- Accurately centred, circular capsulotomies of a specified size. This may allow better long-term intraocular lens centration.
- Reduced corneal endothelial loss as a result of shorter phacoemulsification times and less intraocular fluid flow during surgery (Donaldson et al., 2013)

These potential advantages need to be weighed against the costs of purchasing and maintaining the laser (including employing a laser technician), the additional space required for the laser equipment, and increased operating time (Donaldson et al., 2013).

10.1.1 Review question

- What is the effectiveness of laser-assisted phacoemulsification cataract surgery compared with standard ultrasound phacoemulsification cataract surgery?

10.1.2 Introduction

This review was undertaken by the Cochrane Eyes and Vision Group, in collaboration with the NICE Internal Clinical Guidelines Team.

The aim of this review was to compare the effectiveness of laser assisted phacoemulsification cataract surgery with standard ultrasound phacoemulsification cataract surgery and gather evidence on safety from randomised controlled clinical trials.

The review focused on identifying studies that fulfilled the conditions specified in Table 33. For full details of the review protocol, see Appendix C.

Table 33: PICO inclusion criteria for the review questions on laser-assisted surgery

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery and posterior chamber intraocular lens (IOL) implantation
Intervention	Laser-assisted cataract surgery
Comparator	Standard phacoemulsification cataract surgery
Outcomes	• Intraoperative complications • Postoperative complications • Visual acuity • Patient satisfaction • Vision-related quality of life • Refractive outcomes • Resource use and costs

Randomised controlled trials (RCTs) were included if they compared laser-assisted phacoemulsification cataract surgery with standard ultrasound phacoemulsification cataract surgery. Papers were excluded if they:

- were guidelines, narrative reviews, case studies/reports, case series, reliability studies, diagnostic accuracy studies, non-comparative studies
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- reported studies conducted entirely in non-OECD countries
- were not published in the English language.

For the list of excluded studies with reasons, see Appendix F.

10.1.3 Evidence review

In total, 1,435 unique references were found for this review question, and full-text versions of 38 citations that seemed potentially relevant to this topic were retrieved. Sixteen studies were identified which met the inclusion criteria, 11 were excluded and 11 were ongoing studies where results have not yet been published.

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

10.1.3.1 Description of included studies

Full details of the included studies are found in the evidence tables (see Appendix E). Sixteen RCTs were identified for inclusion in the review, of which 5 were within-person studies where 1 eye of each participant had manual phacoemulsification and the other eye laser-assisted cataract surgery (Conrad-Hengerer 2013; Conrad-Hengerer 2014, Dick 2014, Schargus 2015; Conrad-Hengerer 2015). Eleven studies were parallel group randomised controlled trials (Nagy 2011, Filkorn 2012, Kránitz 2012, Takács 2012, Reddy 2013; Nagy 2014; Kovacs 2014; Mastropasqua 2014a, Mastropasqua 2014b, Hida 2014; Yu 2015).

10.1.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts. A total of 4,306 references were retrieved, of which 1 was retained for this review question.

Abell et al. (2014) conducted a cost–utility analysis of laser-assisted vs standard ultrasound phacoemulsification using a decision tree model. The payer perspective was the private secondary care provider with direct patient and Australian Medicare costs included. The model considers a hypothetical cohort of patients undergoing cataract surgery on the better-seeing eye. Utilities in the model were calculated according to a mathematical relationship between visual acuity and HRQoL proposed based on studies by Brown et al. (1999 & 20020, Lansingh et al. (2009), and Saw et al. (2005) which is given as:

$$y = -0.04792x^3 + 0.191x^2 - 0.4233x + 0.9128$$

y= $utility$

x= $VA\ \text{in}\ LogMAR\ units$

The authors used data on the effectiveness of phacoemulsification taken from the Swedish National Cataract Registry, a multicentre prospective trial (Hahn et al. 2010) and a large cohort study from a tertiary centre in Germany (Hoffman et al. 2011). In the absence of any equivalent evidence on laser-assisted surgery, Abell et al. (2014) assumed that the benefit of femtosecond surgery would be a 5% improvement in the number of eyes achieving ~6/12

visual acuity after surgery The increase in best corrected visual acuity (BCVA) after cataract surgery in the laser group was assumed to reflect improved refraction owing to improved lens positioning as a result of more regular capsulotomy incisions, as well as a decrease in the intraoperative complication rate. Based on the simulated complication rates of standard and laser-assisted surgery and assuming visual acuity improvement of 5% in uncomplicated cases, laser-assisted surgery was associated with QALY gains of 0.06, but was also found to have increased costs, with a resulting ICER of $AUS92,862 per QALY gained, which is above conventional thresholds of cost effectiveness. Multivariable sensitivity analyses revealed that laser-assisted surgery would need to significantly improve visual outcomes and complications rates over standard surgery, along with a reduction in cost to patient, to improve cost effectiveness. Modelling a best-case scenario of laser-assisted surgery with excellent visual outcomes (100% achieving >6/12 vision), a significant 0% complication rate and a significantly reduced total cost to the patient of $AUS300 resulted in an ICER of $AUS20,000 per QALY. The evidence table for the study is included in Appendix E.

10.1.5 Evidence statements

10.1.5.1 Intraoperative complications

Very low-quality evidence from 10 RCTs containing 1,076 participants could not differentiate rates of anterior capsule tear or posterior capsule tear between people given laser-assisted cataract surgery and those given standard ultrasound phacoemulsification.

10.1.5.2 Postoperative complications

Low-quality evidence from up to 9 RCTs containing 957 participants could not differentiate rates of cystoid macular oedema or elevated intraocular pressure between people given laser-assisted cataract surgery and those given standard ultrasound phacoemulsification.

10.1.5.3 Visual acuity

Low-quality evidence from 3 RCTs containing 338 participants could not detect a clinically meaningful difference in postoperative levels of visual acuity (logMAR) between people given laser-assisted cataract surgery and those given standard ultrasound phacoemulsification.

10.1.5.4 Duration of procedure

Low-quality evidence from 3 RCTs containing 274 participants could not differentiate total procedure duration between people given laser-assisted cataract surgery and those given standard ultrasound phacoemulsification.

10.1.5.5 Health Economics

One partly applicable study with potentially serious limitations suggests that laser-assisted cataract surgery is not cost effective when compared to standard phaco-emulsification techniques.

10.1.6 Evidence to recommendations

Relative value of different outcomes	The Guideline committee stated that improvements in either visual outcomes or complication rates with laser-assisted cataract surgery would be relevant, as would differences in procedure duration. It would also be important to consider the inclusion criteria of the studies, as laser-assisted surgery may only be practical in certain

	groups of patients (e.g. those with cataracts which the laser is capable of breaking up).
Trade-off between benefits and harms	The committee agreed that there was no evidence to suggest a clinical difference between using laser assisted and standard phacoemulsification surgery. Whilst the trials in this area had quite small sample sizes, they did not demonstrate any meaningful improvements in visual acuity, visual function or complication rates. The only statistically significant difference was a 1-1.5 letter improvement in corrected visual acuity at 6 months, and this was judged by the committee not to be a clinically meaningful difference, particularly as it was not replicated at other time points, nor was a difference identified in uncorrected visual acuity. The committee therefore agreed it would be inappropriate for laser-assisted cataract surgery to be regularly used. However, they also agreed that, because of the relative scarcity and low quality of the evidence base, and the fact there are specific situations where laser-assisted surgery may have benefits (for example, to improve outcomes for inexperienced surgeons), there could still be value in additional trials comparing laser-assisted surgery with ultrasound phacoemulsification in this situation. Whilst the committee did not feel this need was sufficient to justify recommending future trials (particularly in view of current trials known to be ongoing such as the NIHR funded FACT study), they agreed that it would be appropriate to recommend that the use of laser-assisted surgery could be justified only within the context of clinical trials.
Consideration of health benefits and resource use	The committee agreed that the economic evidence presented was neither directly relevant to the decision problem at hand nor particularly robust, with large amounts of the parameter inputs being based solely on assumptions. Nevertheless, the committee agreed that it still provided useful evidence to inform its decision, as it demonstrated that the benefits it would be necessary for laser-assisted surgery to achieve in order to be cost effective at a population level were much larger than those shown by currently published trials. However, the committee are aware of two large trials with associated health economic evaluations that are due to publish in the next 12 months; (the FACT trial in the UK and the FEMCAT trial in France) which may offer new evidence. The committee also considered that additional research could be undertaken to examine whether femtosecond laser-assisted surgery enables greater surgical throughput and therefore has health-economic benefits with regard to increasing capacity which may offset the higher costs of the procedure compared to standard phacoemulsification. For these reasons, the committee felt an 'only in research' recommendation was appropriate. The committee also noted that there is not only a cost associated with the initial purchase of the laser itself, but also an additional incremental cost for each surgery undertaken, because of required disposables. There are also problems with docking the laser on some patients whose eye characteristics fall outside certain ranges. Therefore, simply having a laser available would not mean that it should be automatically used in all possible procedures.
Quality of evidence	The committee noted that the evidence presented, although of low quality, was largely in line with current clinical opinion and that, although the exclusion criteria in the trials seemed extensive, they agreed that they were reasonable and unlikely to impact on the overall pattern of the evidence.
Other considerations	No other considerations were identified as part of this review question.

10.1.7 Recommendations

34. Do not use femtosecond laser-assisted cataract surgery unless it is part of a randomised controlled trial comparing femtosecond laser-assisted cataract surgery with ultrasound phacoemulsification.

10.2 Bilateral surgery

At present, the majority of patients presenting with bilateral cataracts undergo sequential surgery with an intervening period between operations of weeks or months. This provides opportunities to identify and treat any postoperative complications related to the first-eye surgery and, if necessary, modify the choice of intraocular lens for the second eye according to the refractive outcome of the first operation. However, the risk of complications for patients without ocular comorbidities is small, and patients undergoing sequential surgery may experience significant difficulty with anisometropia whilst waiting for the second-eye operation. Furthermore, the interval between procedures delays the time at which patients regain their full visual potential. Bilateral simultaneous (rapid sequential) cataract surgery may, therefore, offer functional benefits to patients. Such surgery may also have cost advantages in terms of theatre efficiency, and reduced numbers of hospital appointments for the patient.

Some surgeons are now offering bilateral simultaneous cataract surgery to selected patients. During such procedures, the patient usually stays on the operating table after successful completion of the first eye surgery, and new drapes, instruments, irrigating lines and solutions are used for the second eye. Selection criteria for bilateral simultaneous cataract surgery typically include:

- No vision threatening ocular co-morbidities
- No evidence of lens instability
- Axial lengths within a range of 21 to 27 mm

10.2.1 Review questions

- What is the effectiveness of bilateral simultaneous (rapid sequential) cataract surgery compared with unilateral eye surgery?
- What is the appropriate timing of second eye surgery, taking into account issues such as refractive power after first eye surgery?

10.2.2 Introduction

The aim of this review was to identify the correct timing for second eye cataract surgery, and in particular:

- The effectiveness and safety of bilateral simultaneous ('rapid sequential') cataract surgery compared with staged unilateral ('bilateral sequential') surgery.
- If bilateral sequential surgery is undertaken, the correct timing of second eye surgery (which included never undertaking surgery as an option).

The review focused on identifying studies that fulfilled the conditions specified in Table 34. For full details of the review protocol, see Appendix C. The main outcomes for this review were visual acuity, visual function and quality of life after surgery, surgical complication rates, patient satisfaction and resource use/costs.

Table 34: PICO inclusion criteria for the review questions on second eye surgery

Population	Adults (18 years and over) with bilateral cataracts undergoing phacoemulsification cataract surgery with intraocular lens implantation
Interventions	• Bilateral simultaneous cataract surgery • Bilateral sequential cataract surgery, with different lengths of time between the first and second operation • Bilateral cataract surgery versus unilateral cataract surgery
Outcomes	• Visual acuity • Visual function

	• Complication rates (including refractive surprise) • Falls • Health-related quality of life • Patient satisfaction • Resource use and costs

Randomised controlled trials (RCTs) and systematic reviews of RCTs were included if they either compared same-day bilateral cataract surgery with different-day bilateral cataract surgery, or compared differing lengths of timing between different-day bilateral cataract surgeries. Papers were excluded if they:

- were narrative reviews, case studies/reports, case series, reliability studies, diagnostic accuracy studies, non-comparative studies
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- reported studies conducted entirely in non-OECD countries
- were not published in the English language.

For the list of excluded studies with reasons, see Appendix F.

10.2.3 Evidence review

In total, 1,772 references were found for these review questions, and full-text versions of 29 citations that seemed potentially relevant to this topic were retrieved. Three unique RCTs were included (Lundström et al., 2006; Sarikkola et al., 2011; Serrano-Aguillar et al., 2011) focusing on bilateral simultaneous versus bilateral sequential cataract surgery for people with bilateral cataracts; and 3 RCTs were included (Castells et al., 2006; Foss et al., 2006; Laidlaw et al., 1998) looking at the additional value of doing versus not doing second-eye cataract surgery. Six systematic reviews were also identified for this population (Frampton et al., 2014; Gillespie et al., 2012; Ishikawa et al., 2013; Kessel et al., 2015; Lamoureux et al., 2011; Malvankar-Mehta et al., 2015) but these did not provide any additional information that was not available from the RCTs themselves. No RCTs were identified looking at different timings of bilateral sequential cataract surgery.

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

10.2.3.1 Description of included studies

The included studies are summarised in Table 35; full details are found in the evidence tables (see Appendix E). All 6 identified primary studies were randomised controlled trials, 3 comparing same day bilateral cataract surgery with different day bilateral cataract surgery and 3 comparing two eye cataract surgery with single eye cataract surgery for people with bilateral cataracts.

Table 35 Summary of included studies

Study & location	Population	Intervention	Comparator
Castells 2006 Spain	296 people Post first-eye surgery for bilateral cataracts	Surgery in both eyes (2-4 months apart)	Surgery in first eye only
Foss 2006 UK	239 people Post first-eye surgery for bilateral cataracts	Expedited second-eye surgery	Waiting list for second eye surgery

Study & location	Population	Intervention	Comparator
Laidlaw 1998 UK	208 people Post first-eye surgery for bilateral cataracts	Expedited second-eye surgery	Waiting list for second eye surgery
Lundström 2006 Sweden	96 people Cataract with need for surgery in both eyes.	Immediate sequential cataract surgery - both operations performed on the same day.	Delayed sequential cataract surgery – An interval of 2 months between the surgeries.
Sarikkola 2011 Finland	520 people Visually significant bilateral cataract.	Immediate sequential cataract surgery – Both operations performed on the same day	Delayed sequential cataract surgery – An interval of 4-6 weeks between the surgeries
Serrano-Aguilar 2012 Spain	845 people Uncorrected distance visual acuity 20/40 or worse in each eye because of cataract.	Immediate sequential cataract surgery – Both operations performed in the same surgical operating room occupancy	Delayed sequential bilateral cataract surgery – An interval of 6 weeks between the surgeries.

10.2.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts. A total of 4,306 references were retrieved, of which 4 were included for these review questions. Health economic evidence tables for these studies are provided in appendix J. An original health economic model was also available to the committee for this review question, and is described in section 6.1.4.2 of this Guideline and in Appendix J.

10.2.4.1 Bilateral simultaneous versus bilateral sequential

Malvankar-Mehta et al. (2013) developed a decision-tree model of immediate sequential compared with delayed sequential bilateral cataract surgery (ISBCS vs DSBCS). Patients in the DSBCS arm had immediate surgery on 1 eye and then the second eye within a 3-month window if they elected to undergo the second surgery. HRQoL was estimated using the patient preference values generated from visual acuity states in Brown et al. (2000). Surgery was either classified as 'successful' or as a 'failure', with failure meaning that an intraoperative or postoperative adverse event (endophthalmitis, CMO, or 'other complication') occurred. Visual acuity outcomes for endophthalmitis were based on a 1991 study of vitrectomy procedures (Doft, 1991) whereas all other success/failure rates and outcomes were taken from a single Canadian hospital. The relative effectiveness of ISBCS and DSBCS was based on expert opinion. In the base-case analysis, ISBCS dominated DSBCS (was more effective and less costly). A one-way sensitivity analysis did not change this result.

Table 36 Base-case results from Malvankar-Mehta et al. (2013)

Treatment	Absolute		Incremental		
	Costs ($)	Effects (QALYs)	Costs ($)	Effects (QALYs)	ICER ($/QALY)
ISBCS	1,334.08	0.96	-	-	Dominant
DSBCS	2,940.62	0.88	1,606.54	−0.08	Dominated

10.2.4.2 Second-eye surgery versus no second-eye surgery

Busbee et al. (2003) developed a decision-tree-based cost–utility analysis of second-eye surgery based on data from the Patients Outcomes Research Team (PORT) study in the USA, which included 722 participants (mean age 72) undergoing cataract extraction surgery.

The comparator was unilateral pseudophakia, and costs and QALY gains were considered over a life expectancy time horizon. The model included costs for cataract surgery, ambulatory and surgical procedures and retinal procedures. It also included drug expenditure costs associated with cataract surgery for medical and postoperative management. The cost of cataract surgery and management of endophthalmitis, intraocular lens dislocation, cystoid macular oedema and lost lens fragments was assumed to occur close to the initiation of cataract management whereas posterior capsule opacification (PCO) and retinal detachment incurred costs at the mean time of treatment after surgery. No cost information was included for unilateral pseudophakia, and the model assumed that the postoperative visual acuity in the second eye was equal to that of the first-eye surgery. Second-eye cataract surgery resulted in a gain of 0.92 quality-adjusted life-years (QALYs) over 12 years (discounted at 3% per annum). Second-eye cataract surgery resulted in a total discounted health-care cost of US$2,509, giving an estimated cost–utility of second-eye cataract surgery of US$2,727 per QALY gained. No incremental analysis was conducted.

Sach et al. (2010) conducted a cost–utility analysis as part of a trial of second-eye cataract surgery (Foss et al., 2006). The cohort was women over 70 years of age with a history of successful cataract surgery and an operable cataract in the absence of other ocular comorbidities. The comparison was patients on a watchful waiting list. HRQoL was measured using the EQ-5D, and the payer perspective was NHS and PSS with carer costs included in an additional scenario analysis. The mean total cost per patient for the lifetime analysis was £12,171 and £10,887 in the operated and the control group, respectively. The incremental cost effectiveness ratio (ICER) for surgery in the base case was £17,299 per QALY gained. The authors discuss the limitations of the EQ-5D for detecting both the quality of life of patients with a cataract prior to surgery and the gain in HRQoL incurred through surgery, highlighting this as a possible reason for their comparatively high ICERs relative to other studies.

Frampton et al. (2014) developed a cost–utility model based on a systematic review of the clinical effectiveness and cost effectiveness of second-eye cataract surgery. They identified 3 randomised controlled trials (RCTs) of clinical effectiveness, 3 studies of cost effectiveness and 10 studies of health-related quality of life (HRQoL) which met their inclusion criteria and, where possible, were used to inform their economic analysis. Studies did not provide evidence that second-eye surgery significantly affected HRQoL, apart from an improvement in the mental health component of HRQoL as measured by the HUI (Health Utility Index -3) in 1 RCT. The health economic analysis was conducted from the NHS and PSS perspective. It simulated a cohort of patients undergoing either second-eye surgery or continued as unilateral pseudophakia cases. In the surgery arm, people underwent successful surgery or had an intraoperative or late complication (endophthalmitis, retinal detachment, PCO, cystoid macular oedema (CMO), lost-lens fragments; with risks for PCO and retinal detachment modelled time-dependently on a lifetime and 3-year time horizon respectively). Utility losses and costs for adverse events were applied for 1 year, with costs and QALYs discounted at 3.5% per annum. Second-eye surgery generated 0.68 incremental QALYs with an ICER of £1,964. Model results were most sensitive to changes in the utility gain associated with second-eye surgery, but the procedure remained well below conventional limits at £5,734/QALY even when a utility gain of as low as 0.02 was modelled. The model was otherwise robust to changes in parameter values. The probability that second-eye surgery is cost effective at QALY thresholds of £10,000 and £20,000 was 100%.

Table 37 Base-case results from Frampton et al. (2014)

Treatment	Absolute		Incremental		
	Costs (£)	Effects (QALYs)	Costs (£)	Effects (QALYs)	ICER (£/QALY)
No second-eye surgery	411	5.29	-	-	-
Second eye surgery	1,752	5.97	1,341	0.68	1,964

An original economic analysis, described in section 6.1.4.2 of this Guideline, suggestes that for second-eye cases, immediate cataract surgery is shown to be cost effective compared with no surgery in most scenarios, **even if it confers no immediate HRQoL gain**. This is because, as with the first-eye surgery, immediate surgery avoids future QALY losses and costs incurred by leaving the cataract(s) to progress until death. Compared with the first eye, there are slightly more scenarios in which HRQoL gain is necessary to produce an ICER lower than £20,000 / QALY; however, in common with the first eye, all these relate to people aged 90. In most cases, these scenarios also feature a high risk of visual loss. A very similar pattern is shown when comparing no surgery with delayed surgery with an acuity threshold of 6/12: most people are predicted to benefit from immediate surgery even if it confers no HRQoL gain and, in those cases where a gain of HRQoL is necessary to justify the slightly higher cost of immediate surgery, this benefit only has to be of 'very small' magnitude. All these scenarios relate to 90-year-olds and most feature a high risk of visual loss.

Whilst it was not possible, because of structural constraints, to run any probabilistic sensitivity analyses for the model, some deterministic sensitivity analyses were run. These included simulating a more rapid deterioration of VA in people with cataract; including wider NHS costs that would typically fall outside of the NICE reference case; and modelling an alternative acuity threshold of 6/9 in the delayed surgery arm. The model behaved as expected in these scenarios, with faster progression making immediate surgery more cost effective in all cases, regardless of risk factors. Including wider costs, or changing the acuity threshold to 6/6 increased the margin by which cataract surgery, in either eye, has to improve HRQoL for 90 year old patients with higher risk profiles. A full description of the sensitivity analyses is given in Appendix J.

10.2.5 Evidence statements

10.2.5.1 Bilateral simultaneous versus bilateral sequential

10.2.5.1.1 Complication rates

Low- to moderate-quality evidence from 2 RCTs containing 2,613 eyes did not identify meaningful differences in levels of intraoperative, postoperative or serious postoperative complications between people undergoing bilateral simultaneous cataract removal and those undergoing sequential surgery.

10.2.5.1.2 Visual function

High-quality evidence from 1 RCT containing 807 participants found subjective visual function (as measured by the VF-14) improved more in people who received immediate sequential surgery than in those in whom second-eye surgery was delayed, before second-eye surgery in the delayed group.

Moderate-quality evidence from 2 RCTs containing 1,298 participants could not differentiate changes in visual function 1 month after second-eye surgery between people who received immediate sequential surgery and those in whom second-eye surgery was delayed.

Moderate-quality evidence from 1 RCT containing 751 participants could not differentiate changes in visual function 1 year after surgery between people who received immediate sequential surgery and those in whom second-eye surgery was delayed.

10.2.5.1.3 Pain during surgery

Moderate-quality evidence from 1 RCT containing 993 participants could not differentiate the proportions of individuals experiencing pain during surgery between people who received immediate sequential surgery and those in whom second-eye surgery was delayed.

10.2.5.1.4 Patient satisfaction

High-quality evidence from 1 RCT containing 989 participants found there were no meaningful differences in the proportions of people very satisfied with their surgery between people who received immediate sequential surgery and those in whom second-eye surgery was delayed.

Moderate-quality evidence from 1 RCT containing 491 participants could not differentiate the levels of satisfaction with vision after second-eye surgery between people who received immediate sequential surgery and those in whom second-eye surgery was delayed.

10.2.5.1.5 Deviation from target refraction

High-quality evidence from 1 RCT containing 982 eyes found there were no meaningful differences in the proportions of people with a deviation from target refraction <0.5 or <1.0 dioptres between people who received immediate sequential surgery and those in whom second-eye surgery was delayed.

10.2.5.1.6 Visual acuity

Very low-quality evidence from 3 RCTs containing 1,386 participants could not differentiate changes in median visual acuity from preoperative to post-second-eye surgery between people who received immediate sequential surgery and those in whom second-eye surgery was delayed.

10.2.5.1.7 Health economics

One partially applicable CUA with serious limitations suggests that immediate sequential cataract surgery dominates (is more effective and cheaper than) delayed sequential surgery, although uncertainty around the estimate of cost effectiveness could not be reliably established.

10.2.5.2 Second-eye surgery versus no second-eye surgery

High-quality evidence from 3 RCTs containing 685 participants found higher levels of best-corrected visual acuity (logMAR) and binocular contrast sensitivity (measured using a Pelli–Robson chart) in people offered second-eye surgery versus no surgery.

High-quality evidence from 1 RCT containing 274 participants found higher levels of improvement in stereopsis (measured using the Titmus circles, Fly and TNO tests, reported in log seconds of arc), self-reported trouble with vision (measured using a 4 item Likert scale) and self-reported satisfaction with vision (measured using a 4 item Likert scale) for people offered second-eye surgery versus no surgery.

High-quality evidence from 2 RCTs containing 503 participants found higher levels of visual function (measured using the VF-14) in people offered second-eye surgery versus no surgery.

Moderate-quality evidence from 1 RCT containing 229 participants could not differentiate the risk of falls or changes in quality of life (as measured by the EQ-5D) between people offered second-eye surgery versus no surgery.

10.2.5.2.1 Health economics

One partially applicable cost–utility analysis from the USA with very serious limitations suggests that second-eye cataract surgery is cost effective under the condition that the gains in visual acuity and HRQoL are at least as large as those generated by the first-eye surgery.

One directly applicable study with minor limitations suggests that second-eye surgery is cost effective compared with unilateral surgery in an NHS context. In a probabilistic sensitivity analysis, the probability that second-eye surgery is cost effective at a willingness-to-pay threshold of £20,000 per QALY was 100%.

One directly applicable CUA, with potentially serious limitations found that second-eye surgery is cost effective when a lifetime time-horizon is considered, and wider costs to carers are excluded from the analysis.

One directly applicable original health economic analysis with potentially serious limitations suggests that for second eyes:

1) Cataract surgery is cost effective compared with no surgery in most scenarios, even if it confers no immediate HRQoL gain.
2) Compared with delayed surgery, most people derive cost-effective benefit from immediate surgery even if it confers no HRQoL gain and, in older, higher-risk cases where a gain of HRQoL is necessary to justify the slightly higher cost of immediate surgery, this benefit only has to be of 'very small' magnitude (see Appendix J).

The model results were somewhat sensitive to the inclusion of ‘unrelated’ costs after surgery for first and second eyes, and the assumed rate at which visual acuity declines in symptomatic eyes.

10.2.6 Evidence to recommendations

Relative value of different outcomes	The committee noted that the relevant outcomes for this comparison were the trade-off between short and long-term differences in visual outcomes, compared with the risk of more serious complications with simultaneous surgery. Committee members agreed that the best available outcomes measures would be vision, health-related quality of life and patient satisfaction, but that, in the absence of these measures, visual acuity, visual function, contrast sensitivity and stereopsis would together provide proxies for at least a substantial proportion of the pre- to post-surgery changes.
Trade-off between benefits and harms	The committee agreed that the evidence demonstrated a clear clinical benefit from second-eye surgery, compared to no second-eye surgery, across a range of domains including visual acuity, visual function, contrast sensitivity and patient satisfaction. Therefore, the key decision would be around the cost effectiveness of second-eye surgery, as discussed in the section on health benefits and resource use below. The committee noted that the studies provided no evidence of differences in long-term visual outcomes, or of rates of common intra- or postoperative complications between same-day and different-day bilateral surgery. The key trade-off was therefore identified as being between short-term benefits with simultaneous surgery versus the risk of more severe complications. Simultaneous surgery gave better outcomes in the period before second-eye surgery in the sequential

	group, with the duration of these additional benefits depending on the time between sequential in the sequential group. Conversely, simultaneous surgery had the potential for more severe adverse events, as it is possible that loss of vision in both eyes could result from a single error, whilst in the sequential group only 1 eye would be damaged through a single mistake. The committee noted that it is still unclear what the likelihood of severe complications (damage to both eyes) is with simultaneous surgery, and therefore people should be given specific information about the potential for additional risks whenever same-day surgery is being considered. The committee agreed it was therefore appropriate that a 'consider' recommendation be made for bilateral simultaneous cataract surgery, but did not feel it appropriate to make a stronger recommendation than this, both because of the lack of robust data on rare adverse events, and because of the relatively restrictive inclusion criteria in the RCTs. They also agreed that, for people at a low risk of complications, there was no overwhelming clinical reason to prefer one timing of second surgery to another, and therefore it was important for people to be given information on the potential benefits and harms of both approaches, in order for them to be able to make an informed decision. No evidence was found to inform any recommendations about the appropriate length of time between procedures performed on different days. Some participants in the control arms of the trials did have intraocular lens adjustments after the first surgery in an attempt to improve second surgery outcomes, and the committee noted that the gap between surgeries needs to be large enough for the refraction to have stabilised after surgery. However, in the absence of any evidence, the committee did not feel it was appropriate to recommend a specific length of time between first and second eye surgeries.
Consideration of health benefits and resource use	The committee considered the modelling study by Malvankar-Mehta et al. (2013) in the light of the clinical evidence presented at the meeting, and discussed in particular the contrasts between the carefully selected populations included in the clinical studies and the hypothetical cohort included in the model. The committee was uncomfortable with the model's lack of external validity; success rates for surgery, adverse event rates, and the rate at which patients elected to have second-eye surgery were all based on the clinical experience of clinicians at a single centre. The committee noted that it would have been possible, given the availability of published evidence in this domain, to undertake a fuller sensitivity analysis of these parameters using evidence external to the centre. The committee considered that there may have been some pressure on the centre to not use data other than expert opinion for surgical outcomes, and that this was a potential source of bias in the analysis. In common with the evidence presented for the questions on indicators and thresholds for surgery (chapter 6), the committee felt that the true costs of adverse events and their HRQoL implications were underestimated by the model, and that the apparent difference in absolute costs between delayed and immediate sequential surgery was primarily driven by the need for two admissions in the delayed surgery arm, and that this cost appeared overestimated. The committee agreed that the small incremental utility gain noted by Sach et al. (2010) and Frampton et al. (2014) was conservative, and was likely driven by the lack of sensitivity of the EQ-5D to both the pre-surgical morbidity of cataract, and the post-surgical gain in HRQoL. Furthermore, these analyses assumed that the difference in utility between second-eye surgery and no second-eye surgery was

constant until death, and as Sach et al (2010) note in their conclusions, this is unrealistic as non-operated cataracts are likely to incur a decrease in visual acuity over time, with related HRQoL losses which could be prevented by offering surgery. The committee felt that the one-year time horizon in Sach et al. was not appropriate, as the benefits (and some potential harms) from surgery were likely to be lifelong. Shorter timescales would also inflate the true lifetime costs by excluding discounting. The committee broadly agreed with the costs included in these studies, although it noted that the carer-costs included in a sensitivity analysis in Sach et al. are not included in the NICE reference case. The committee noted the increased non-ocular NHS costs following cataract surgery (driven by greater uptake of GP visits, A&E appointments, and nurse visits in the surgery group), and expressed the view that these were somewhat surprising. One possible explanation was that improving people's visual impairment empowers them to seek healthcare for other issues; another is that simply being in the hospital environment increases the likelihood of accessing other services. However, the committee understood that such costs should usually be considered as 'unrelated' and therefore excluded from consideration in the NICE reference case.

The committee noted that the systematic review of effectiveness evidence in Frampton (2014) meant that the model was parameterised with data that is now 10 years old, and that in that time surgical outcomes have continued to improved and more second-eye surgeries are being performed. Furthermore, the committee discussed how the modelled cohort did not reflect the range of acuity and morbidity seen in clinical practice, and noted that the cohort had generally good preoperative acuity which would tend to make the reported QALY gains more conservative.

The committee was presented with results from the original model undertaken for this guideline, which concluded that second-eye cataract surgery is likely to be cost effective in most cases even if it confers no immediate HRQoL gain (see chapter 6). This is because immediate surgery avoids future QALY losses and costs incurred by leaving the cataract(s) to progress until death.

Compared with the first eye, the committee was mindful that there are slightly more scenarios in which HRQoL gain is necessary to produce an ICER lower than £20,000 / QALY; however, in common with the first eye, all these relate to people aged 90. In most cases, these scenarios also feature a high risk of visual loss, but even then only a 'very small' immediate HRQoL benefit is required to make surgery cost effective. Therefore, the committee agreed that immediate second-eye cataract surgery, without any requirement for acuity thresholds, would invariably be the optimal strategy as it saves future costs and QALY losses. The committee noted that the model results were on the whole very similar for first-operated eyes, and that it was common that in their own practice for first-eye patients to request second-eye surgery because they found the first-eye surgery to be beneficial. The original model was not designed to provide a dynamic simulation of these potential concerns.The committee discussed the likely resource and capacity impacts of recommending immediate referral, particularly the increased demand for surgery and associated pressures on capacity. The consensus of the group was that this would likely be a short-term increase in demand as those people with visual acuity below thresholds (in trusts where they currently apply) would move to waiting lists, but that after that initial increase there would be a return to a steady state.

This is supported by the Royal College of Ophthalmology NOD studies which show that the modal acuity for first-eye patients is 6/6. Therefore, the committee considered that using the same criteria as

	recommended for first-eye surgery in Section 6 of the Guideline when deciding to offer second-eye surgery was logical and justified by these models.
Quality of evidence	The committee agreed that the evidence presented was robust, both in demonstrating the clear clinical benefits of second-eye surgery versus no second-eye surgery, and in demonstrating that there were no major differences in the long-term visual outcomes of same day or different day surgery in the groups recruited, but agreed that there were 2 major limitations in the evidence base. Firstly, the sample sizes were too small to pick up potential differences in rare but catastrophic complications, which are the main reason for concern with simultaneous surgery. Secondly, the populations in the trials were very carefully selected to only include those people with low risk of intra- or postoperative complications, and therefore no evidence was available on outcomes for people at higher risk, such as those with ocular comorbidities. Therefore, the committee decided it would only be appropriate to recommend simultaneous surgery as an option in the population covered by the trials, specifically those at low risk of intra- or postoperative complications.
Other considerations	No other considerations were identified as being relevant for this review question.

10.2.7 Recommendations

35. Offer second-eye cataract surgery using the same criteria as for the first eye surgery (see section 6 for referral for cataract surgery).

36. Consider bilateral simultaneous cataract surgery for people who are at low risk of complications during and after surgery.

37. Discuss the potential benefits and harms of bilateral simultaneous cataract surgery with people, which should include:

- the potential immediate visual improvement in both eyes
- how it will not be possible to choose a different intraocular lens based on the outcome in the first eye
- the risk of complications in both eyes during and after surgery that could cause long-term visual impairment
- the likely need for additional support after the operation.

11 Anaesthesia

Ophthalmic anaesthesia is a recognised sub-specialty of anaesthetic practice, providing care for a wide range of patients, from neonates to the very elderly. Importantly, the quality of anaesthesia can have a direct impact on the operating field, so close team-working with surgical colleagues is essential.

Local anaesthesia for cataract surgery can be undertaken using a variety of methods including topical (+/- intracameral) local anaesthesia, sub-Tenon's anaesthesia (using a blunt cannula), or one of the sharp needle techniques such as peribulbar or retrobulbar block. Recent estimates of current use of these techniques for cataract surgery in the UK are 39%, 51%, 9% and 1% respectively (Lee et al., 2016). General anaesthesia is also an option, and tends to be reserved for patients not suitable for local anaesthesia, or where surgery is considered to be of unusually high risk.

When deciding which technique to use, a large number of factors need to be taken into consideration. These include patient factors such as compliance, level of anxiety, pre-existing medical conditions; surgical factors such as anticipated technical difficulty, desirability for globe akinesia; and anaesthetic factors such as success rate versus the risks involved from the technique itself (Lee et al., 2016; Eke et al., 1999; Eke et al., 2007). Organisational issues may also be important such as cost and theatre efficiency, and the availability of skilled ophthalmic anaesthetic cover.

Availability of monitored sedation may also be important for some patients. Undergoing surgery on the eye can be extremely stressful for certain individuals and current UK sedation rates for cataract surgery (4%, Lee et al., 2016) fall well below rates measured in other OECD countries (60–88% Australia [Clarke et al., 2016], >77% in the USA [Betsy Lehman Center, 2016]). Due to the unique patient case-mix, difficult intraoperative patient access and the potentially disastrous consequences of unexpected patient movement, sedation should only be undertaken by trained ophthalmic anaesthetists using carefully titrated anxiolytic agents.

One aspect for future consideration is the likely increase in the number of patients needing cataract extraction that have some degree of coincidental age-related dementia. This could be as high as 5% of patients attending ophthalmic outpatients and these patients may well require more input from dedicated ophthalmic anaesthetists to enable safe and effective surgical intervention (Kumer et al., 2016). It is essential, therefore, that ophthalmic anaesthesia remains an integral part of the package of ophthalmic care available to future generations.

11.1 Type and administration of anaesthesia

11.1.1 Review question

- What is the optimal type and administration of anaesthesia for cataract surgery?

11.1.2 Introduction

The aim of this review was to determine the optimal type and method of administration of anaesthesia for phacoemulsification cataract surgery. The review focused on identifying studies that fulfilled the conditions specified in Table 38. For full details of the review protocol, see Appendix C. The main outcomes for this review were intraoperative pain, pain on administration of anaesthesia, surgical and anaesthetic related complication rates and patient satisfaction.

Table 38: PICO criteria –optimal type and administration of anaesthesia

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery for non-trauma related cataracts and intraocular lens (IOL) implantation
Interventions	Methods: • Peribulbar/periocular block • Retrobulbar block • Sub-Tenon's anaesthesia • Topical (drops) ± intracameral (diluted with saline) Drugs: • Lidocaine/xylocaine • Bupivacaine • Benoxinate
Comparators	• Different methods vs. each other • Different drugs vs. each other • Warming of drug vs. no warming of drug
Outcomes	• Intraoperative pain • Pain on administration of anaesthesia • Surgical complication rates • Anaesthetic-related complications • Patient satisfaction • Resource use and costs

Papers were excluded if they:

- were not randomised controlled trials
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

11.1.3 Evidence review

In total, 2,676 references were found from a database search for all the review questions looking for randomised controlled trials on anaesthesia, and full-text versions of 90 citations that seemed potentially relevant to this topic were retrieved and screened at full-text.

The design of included studies is summarised in Table 39. Full details and results are found in the evidence tables (see Appendix E). Forty one studies were included in this review (4 systematic reviews and 37 additional RCTs not included in any of those reviews).To enable all relevant data to be included as part of the meta-analyses, all continuous pain and patient satisfaction measures were converted to a 0–100 scale before analysis.

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

Table 39: Summary of included studies – optimal type and administration of anaesthesia

Study & location	Population	Methods
Jaichandran et al. (2010) India	100 patients	RCT on the effect of lidocaine warming and alkalinisation on injection pain, motor and sensory nerve blockade.
Krause et al. (1997) Germany	70 patients	RCT to investigate the effect of warming local anaesthetic solutions on pain of injection and on bulbar akinesia and analgesia of retrobulbar anaesthesia
Ursell et al. (1996) UK	40 patients	RCT to investigate the effect of warming local anaesthetic solutions on pain of injection for peribulbar anaesthesia
Soliman et al. (2004) Egypt	60 patients	RCT comparative clinical trial of topical anaesthetic agents in cataract surgery.
McLure et al. (2005) UK	91 patients	RCT comparison of lidocaine 2% with levobupivacaine 0.75% for sub-Tenon's block
Naeem et al. (2007) India	200 patients	RCT comparison of peribulbar vs topical anaesthesia for phacoemulsification
Zhao et al. (2012) China	1369 eyes (8 RCTs)	Topical anaesthesia versus Regional anaesthesia for cataract surgery: A Meta-analysis of Randomized Controlled Trials – systematic review
Guay et al. (2015) Canada	617 patients (7 RCTs)	Sub-Tenon's anaesthesia versus topical anaesthesia for cataract surgery – systematic review
Ezra et al. (2010) UK	1281 patients (8 RCTs)	Topical anaesthesia alone versus topical anaesthesia with intracameral lidocaine for phacoemulsification – systematic review
Alhassan et al. (2015) Nigeria	1438 patients (6 RCTs)	Peribulbar versus retrobulbar anaesthesia for cataract surgery – systematic review
Nielson et al. (1998) Denmark	66 patients	Evaluation of local anaesthesia techniques for small incision cataract surgery
Ahmad et al. (2012) Saudi Arabia	80 patients	RCT looking at satisfaction level with topical versus peribulbar anaesthesia experienced by the same patient for phacoemulsification.
Sekundo et al. (2004) Germany	100 patients	RCT comparing Lidocaine and sub-Tenon anaesthesia – included in Guay Systematic Review

Study & location	Population	Methods
Srinivasan et al. (2004) UK	201 patients	RCT comparing topical and sub-Tenon's anaesthesia in routine cataract surgery– included in Guay Systematic Review
Vielpeau et al. (1999) France	50 patients	RCT comparing topical and sub-Tenon's anaesthesia for cataract surgery– included in Guay Systematic Review
Boulton et al. (2000) Australia	192 patients	RCT of intracameral lidocaine during phacoemulsification under topical anaesthesia– included in Ezra Systematic Review
Crandall et al. (1999) USA	136 patients	RCT comparing patient comfort during cataract surgery with topical versus topical anaesthesia with intracameral – included in Ezra Systematic Review lidocaine
Gillow et al. (1999) UK	200 patients	RCT to determine the efficiency of supplementary intracameral lidocaine in routine phacoemulsification under topical anaesthesia– included in Ezra Systematic Review
Roberts et al. (2002) Australia	135 patients	RCT comparing cataract surgery under topical anaesthesia with and without intracameral lignocaine– included in Ezra Systematic Review
Tseng et al. (1998) China	162 patients	RCT evaluating patient discomfort during phacoemulsification while under topical lidocaine alone or in combination with intracameral lidocaine– included in Ezra Systematic Review
Carino et al. (1998) Canada	60 patients	RCT comparing topical tetracaine versus topical tatracaine plus intracameral lidocaine for cataract surgery– included in Ezra Systematic Review
Gills et al. (1997) USA	303 patients	RCT to determine whether intraoperative lidocaine decreases pain during cataract surgery– included in Ezra Systematic Review
Martin et al. (1998) USA	93 patients	RCT comparing safety and efficiency of intracameral injections of lidocaine to reduce intraocular sensation– included in Ezra Systematic Review
Zafirakis et al. (2001) Greece	200 patients	RCT comparing topical and sub-Tenon's anaesthesia without sedation in cataract surgery– included in Guay Systematic Review
Mathew et al. (2003) UK	119 patients	RCT comparing patient comfort during phacoemulsification cataract surgery with sub-Tenon's anaesthesia– included in Guay Systematic Review
Chittenden et al. (1997) UK	37 patients	RCT comparing topical and sub-Tenon's anaesthesia for small incision cataract surgery– included in Guay Systematic Review
Athanikar et al. (1991) India	142 patients	RCT comparing Peribulbar and Retrobulbar anaesthesia – included in Alhassan Systematic Review
Weiss et al. (1989) USA	79 patients	RCT comparing retrobulbar and periocular anaesthesia for cataract surgery– included in Alhassan Systematic Review
Ali-Malkkila et al. (1992) Finland	300 patients	RCT comparing regional anaesthesia for cataract surgery: comparison of 3 techniques– included in Alhassan Systematic Review
Ali-Malkkila et al. (1993)	450 patients	RCT comparing Retrobulbar and Peribulbar techniques for cataract surgery– included in Alhassan Systematic Review

Study & location	Population	Methods
Finland		
Wong et al. (1993) Canada	150 patients	RCT comparing Peribulbar and Retrobulbar anaesthesia for cataract surgery– included in Alhassan Systematic Review
Feibel et al. (1993) USA	317 patients	RCT comparison of peribulbar and retrobulbar anaesthesia – included in Alhassan Systematic Review
Jacobi et al. (2000) Germany	476 patients	RCT comparing topical vs retrobulbar anaesthesia in complicated cataract surgery– included in Zhao Systematic Review
Patel et al. (1996) USA	138 patients	RCT comparison of topical and retrobulbar anaesthesia for cataract surgery - included in Zhao Systematic Review
Patel et al. (1998) USA	90 patients	RCT evaluation of topical versus retrobulbar anaesthesia- included in Zhao Systematic Review
Ryu et al. (2009) South Korea	54 patients	RCT comparison of retrobulbar block, sub-Tenon block and topical anaesthesia during cataract surgery- included in Zhao Systematic Review
Sauder et al. (2003) Germany	140 patients	RCT comparing topical versus peribulbar anaesthesia for cataract surgery- included in Zhao Systematic Review
Uusitalo et al. (1999) Finland	299 patients	RCT evaluating converting to topical anaesthesia in cataract surgery - included in Zhao Systematic Review
Virtanen et al. (1998) Finland	100 patients	RCT evaluating pain in scleral pocket incision cataract surgery using topical and peribulbar anaesthesia - included in Zhao Systematic Review
Zehetmayer et al. (1996) Austria	72 patients	RCT evaluating topical versus peribulbar anaesthesia in cataract surgery- included in Zhao Systematic Review
Gombos et al. (2007) Hungary	115 patients	RCT comparing effectiveness of topical versus retrobulbar anaesthesia for cataract surgery- included in Zhao Systematic Review

11.1.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

11.1.5 Evidence statements

11.1.5.1 Warming vs no warming

Low-quality evidence from 3 RCTs containing 210 participants found that people who received anaesthetic warmed to 37ºC reported lower injection pain scores than those who received anaesthetic at room temperature during cataract surgery.

11.1.5.2 Network meta-analyses (pain)

11.1.5.2.1 Anaesthetic drug

Moderate-quality evidence from a network-meta analysis of 2 RCTs containing 181 participants found that benoxinate and bupivacaine are associated with lower levels of pain during application of anaesthesia than lidocaine and levobupivacaine.

Moderate-quality evidence from a network-meta analysis of 2 RCTs containing 181 participants found that lidocaine and levobupivacaine are associated with lower levels of pain during surgery than benoxinate and bupivacaine, and bupivacaine is associated with lower levels of pain than benoxinate.

11.1.5.2.2 Method of anaesthesia

Moderate-quality evidence from a network-meta analysis of 6 RCTs containing 973 participants found that retrobulbar anaesthesia is associated with higher levels of pain during application of anaesthesia than peribulbar, sub-Tenon's or topical anaesthesia.

Moderate-quality evidence from a network-meta analysis of 20 RCTs containing 3,172 participants found that sub-Tenon's anaesthesia is associated with lower levels of pain during surgery than topical or topical plus intracameral anaesthesia, and that both retrobulbar and peribulbar anaesthesia are associated with lower levels of pain than topical anaesthesia alone.

11.1.5.3 Anaesthetic drug (other outcomes)

11.1.5.3.1 Lidocaine vs bupivacaine

Low-quality evidence from 1 RCT containing 60 participants could not differentiate the proportions of people willing to have the same anaesthetic again between people who received either lidocaine or bupivacaine during cataract surgery.

11.1.5.3.2 Lidocaine vs benoxinate

Moderate-quality evidence from 1 RCT containing 60 participants found that people who received lidocaine were more likely to be prepared to have the same anaesthetic again than those who received benoxinate.

11.1.5.3.3 Bupivacaine vs benoxinate

Moderate-quality evidence from 1 RCT containing 60 participants found that people who received bupivacaine were more likely to be prepared to have the same anaesthetic again than those who received benoxinate.

11.1.5.3.4 Lidocaine vs levobupivacaine

Low- to very low-quality evidence from 1 RCT containing 91 participants could not differentiate the risks of a small subconjunctival haemorrhage or chemosis developing during cataract surgery for people who received either lidocaine or levobupivacaine anaesthetic.

11.1.5.4 Method of anaesthesia (other outcomes)

11.1.5.4.1 Topical vs retrobulbar

Low-quality evidence from 1 RCT containing 86 participants could not differentiate the proportion of people preferring topical or retrobulbar anaesthesia during cataract surgery.

Moderate-quality evidence from 1 RCT containing 86 participants found that people who received retrobulbar anaesthesia were less prepared to have the anaesthetic procedure again compared with people who received topical anaesthesia during cataract surgery.

11.1.5.4.2 Topical vs sub-Tenon's block

Low-quality evidence from 1 RCT containing 86 participants could not differentiate the proportion of people preferring topical anaesthesia or a sub-Tenon's block during cataract surgery.

Low-quality evidence from 1 RCT containing 86 participants could not differentiate the proportions of people prepared to repeat either topical anaesthesia or a sub-Tenon's block during cataract surgery.

Very low- to moderate-quality evidence from up to 3 RCTs containing 351 participants could not differentiate the risks of postoperative iritis, iris prolapse, posterior capsule tear or subconjunctival haemorrhage developing in people who received either a sub-Tenon's block or topical anaesthesia during cataract surgery, but did find a higher risk of chemosis in people given a sub-Tenon's block.

11.1.5.4.3 Topical vs topical with intracameral anaesthesia

Moderate-quality evidence from 5 RCTs containing 459 participants could not differentiate the risk of an adverse surgical event during cataract surgery for people who received either topical or topical with intracameral anaesthesia.

11.1.5.4.4 Peribulbar vs Retrobulbar

Low- to high-quality evidence from up to 7 RCTs containing 2,075 participants found that people who received peribulbar anaesthesia were at greater risk of developing conjunctival chemosis than those who received retrobulbar anaesthesia during cataract surgery, but those who received retrobulbar anaesthesia were at higher risk of developing a lid haematoma. The evidence could not differentiate rates of retrobulbar haemorrhage or ptosis.

11.1.5.4.5 Retrobulbar vs sub-Tenon's block

Low-quality evidence from 1 RCT containing 86 participants could not differentiate the proportion of people preferring a sub-Tenon's block or retrobulbar anaesthesia during cataract surgery.

Moderate-quality evidence from 1 RCT containing 86 participants found that people who received retrobulbar anaesthesia were less prepared to have the anaesthetic procedure again compared with a sub-Tenon's block during cataract surgery.

11.1.5.4.6 Topical vs retro/peribulbar

High-quality evidence from 1 systematic review of 4 RCTs containing 266 participants found that people who received retro/peribulbar anaesthesia were less likely to be satisfied with the anaesthetic procedure than those who received topical anaesthesia.

Very low- to moderate-quality evidence from 1 systematic review reporting a total of 1,359 participants could not differentiate the risks of a capsule rupture, zonular tear or iris prolapse developing during cataract surgery in people who received either topical or retro/peribulbar anaesthesia, but did find higher rates of chemosis, periorbital haematoma and subconjunctival haemorrhage in people given retro/peribulbar anaesthesia.

11.1.5.5 Health Economic Evidence

No health economic evidence was identified for this review question.

3645

3646 ### 11.1.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that intraoperative pain, pain on administration of anaesthesia, complication rates and patient satisfaction would all be relevant outcomes. They also agreed that, for most people, pain on administration was not as important a concern as pain during surgery.
Trade-off between benefits and harms	The committee agreed that surgeons are often reluctant to change the method of anaesthesia they use, as each has an effect on how the eye behaves for surgery, such as the lens sitting deeper in the eye, which may impact on surgical technique. It discussed the risks associated with the use of retrobulbar injections as, although they are rare, severe, life-threatening complications can arise from its use (e.g. hitting the optic nerve or severe haemorrhage). It agreed that, in the absence of any benefits noted from retrobulbar injections over and above other methods of anaesthesia, its use could no longer be justified. The committee agreed with the evidence that peribulbar anaesthesia was not meaningfully more efficient in terms of pain relief, and felt that some of the serious complications seen in clinical practice, including globe perforation, were not captured in the studies presented, due to the relatively small sample sizes of the studies. It did, however, note that the evidence showed periorbital haematoma was more prevalent with peribulbar and retrobulbar injections compared with topical anaesthesia, showing the increased potential for vascular injury associated with deep injections (confirming the group's experience that more serious, albeit rarer, vascular injuries can result for this approach). The committee agreed that individual patient characteristics often influence the preferred method of anaesthetic delivery, and highlighted that it would be safer for those on anticoagulants to receive a sub-Tenon's block rather than a retrobulbar or peribulbar injection, as it is less likely to cause severe retrobulbar haemorrhage. Similarly, in patients with small pupils, greater pain may be experienced due to the use of iris hooks and dilators, and thus sub-Tenon's anaesthesia may be of benefit. However, it noted that an exception would be where the patient had undergone previous eye surgery, in such cases a peribulbar injection may be necessary as it may not possible to give sub-Tenon's anaesthesia. The committee agreed that most patients given a topical anaesthetic would achieve an appropriate level of anaesthesia without the addition of an intracameral injection, assuming they had a well dilated pupil, but added that some patients may benefit substantially in reduced pain during surgery. It agreed that this would result in an overall small average gain in giving the additional intracameral injection. The committee agreed that there was evidence to suggest a clinical difference in analgesic effect from using a sub-Tenon's block when compared with the other methods of delivery, but noted that this is a more invasive procedure when compared with topical anaesthesia. The group also highlighted that some surgeons do not allow enough time for the anaesthetic to penetrate the muscle, thus believing it less effective for akinesia. From this viewpoint the committee believed that patients may choose topical 'a priori'. The committee agreed that, considering the evidence as a whole, both topical and sub-Tenon's anaesthesia represented reasonable treatment options, with peribulbar only an acceptable choice if both these other methods were contraindicated.

Consideration of health benefits and resource use	No economic evidence was identified for this review question and economic modelling was not prioritised. The committee discussed the need for a specialist ophthalmic anaesthetist to give a retrobulbar or peribulbar injection, and thus the additional costs associated, whereas one was not needed in order to give sub-Tenon's or topical (with or without intracameral) anaesthesia. However, it was noted that surgeons may have to consider giving a peribulbar injection under specific circumstances such as for those who have undergone previous surgery for retinal detachment. It was also highlighted that there could also be an additional resource cost with sub-Tenon's block due to the use of syringes and needles when compared with topical application, although the routine use of topical with intracameral anaesthesia would imply additional costs along with the theoretical risk of infection.
Quality of evidence	The committee agreed that, on the whole, the evidence reflected the treatment alternatives in practice. One exception was evidence looking at benoxinate versus lidocaine, which was drawn from a single RCT from Egypt. The committee expressed the view that outcomes from this trial did not mirror UK experience. It noted that the mean verbally reported pain of people receiving benoxinate was around 7/10, and agreed that, if the majority of their patients were reporting similar pain levels, committee members would have noted this and it would be considered well outside acceptable limits. It also commented on the comparison of lidocaine gel with eye drops; a gel may be present longer on the eye and thus afford greater anaesthetic effect, but the approach may also be associated with higher rates of infection and is not commonly used in the UK. It was noted that no evidence of proxymetacaine was presented, which is very commonly used in the UK. The committee noted there was some evidence of a pattern of drugs that resulted in higher pain on application being associated with less pain during surgery, but agreed that the problems with the evidence base meant it was not possible to be confident in this finding. Taking the inconsistencies and absences in the available evidence into account, the committee concluded it was not appropriate to make any recommendations on which drugs should be preferred for anaesthesia. The committee agreed that, although the exclusion criteria in the trials seemed quite extensive on occasion, they were reasonable and unlikely to impact on the overall pattern of the evidence. The committee discussed the study dates for topical anaesthesia, commenting that it believed this particular method of anaesthesia had improved in efficacy since the early 2000s when many of the studies presented were undertaken. The committee agreed that there was evidence of benefit for the warming of anaesthetic, but noted this evidence came from peribulbar and retrobulbar anaesthesia. It did not believe it was necessary appropriate to extrapolate this to use in sub-Tenon's and topical methods of anaesthesia delivery, and as such were not prepared to make recommendations on the evidence presented.
Other considerations	No other considerations were identified for this review question.

11.1.7 Recommendations

38. Offer sub-Tenon's or topical (with or without intracameral) anaesthesia for people having cataract surgery.

39. If both sub-Tenon's and topical (with or without intracameral) anaesthesia are contraindicated, consider peribulbar anaesthesia.

40. Do not offer retrobulbar anaesthesia for people having cataract surgery.

11.2 Sedation as an adjunct to local anaesthesia

11.2.1 Review question

- What is the effectiveness of sedation as an adjunct to local anaesthesia during cataract surgery?

11.2.2 Introduction

The aim of this review was to determine the effectiveness of sedation as an adjunct to local anaesthesia during phacoemulsification cataract surgery. The review focused on identifying studies that fulfilled the conditions specified in Table 40. For full details of the review protocol, see Appendix C. The main outcomes for this review were intraoperative pain, pain on administration of the anaesthesia and patient satisfaction.

Table 40 PICO criteria – effectiveness of sedation as an adjunct to local anaesthesia

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery for non-trauma related cataracts and intraocular lens (IOL) implantation
Interventions	Sedation (midazolam, fentanyl, propofol)
Comparator	No sedation
Outcomes	• Intraoperative pain • Pain on administration of anaesthesia • Surgical complication rates • Anaesthetic-related complications • Patient satisfaction • Resource use and costs

Papers were excluded if they:

- were not randomised controlled trials
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

11.2.3 Evidence review

In total, 2,676 references were found from a database search for all the review questions looking for randomised controlled trials on anaesthesia, and full-text versions of 10 citations that seemed potentially relevant to this topic were retrieved and screened at full-text. Two randomised controlled trials were included (Inan et al., 2003 and Aydin et al., 2002).

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

The design of included studies is summarised in Table 41. Full details and results are found in the evidence tables (see Appendix E).

Table 41 Summary of included studies – effectiveness of sedation as an adjunct to local anaesthesia

Study & location	Population	Methods
Inan et al. (2003) Turkey	120 people	RCT to determine the effects of systemic fentanyl in preventing the pain related to the administration of retrobulbar anaesthesia and cataract surgery.
Aydin et al. (2002) Turkey	68 people	RCT to investigate the effects of sedation/analgesia with fentanyl during phacoemulsification surgery under topical anaesthesia.

11.2.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

11.2.5 Evidence statements

11.2.5.1 Pain scores on application of the anaesthetic

Moderate-quality evidence from 1 RCT of 120 participants found that those who received local anaesthetic and fentanyl reported lower pain scores on the application of anaesthetic than those who received local anaesthetic alone.

11.2.5.2 Pain scores during surgery

Moderate-quality evidence from 1 RCT of 120 participants found that those who received local anaesthetic and fentanyl reported lower pain scores during cataract surgery than those who received local anaesthetic alone.

11.2.5.3 Patient satisfaction

High-quality evidence from 1 RCT of 68 participants found that those who received local anaesthetic and fentanyl were more satisfied with the analgesia than those who received local anaesthetic alone.

11.2.5.4 Health Economic Evidence

No health economic evidence was identified for this review question.

11.2.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that intraoperative pain, pain on administration of the anaesthesia and patient satisfaction would all be relevant outcomes. It agreed that patient satisfaction would be at least partially independent of reported pain due to the anxiolytic effect of sedation.
Trade-off between benefits and harms	The committee agreed that there was evidence to suggest that fentanyl was successful in reducing reported pain on application of anaesthetic and during surgery, and increasing patient satisfaction. However no evidence was found on the use of midazolam or propofol, both of which are also commonly used in the UK. The committee agreed that, of all 3 of these options, fentanyl had the

	largest analgesic and lowest anxiolytic effect, and therefore the evidence did not entirely capture the effect of sedation alone. The committee discussed whether it was possible to prospectively identify patients who may require/benefit from sedation and it was agreed that those with a large degree of anxiety would benefit most, although the committee noted that intraoperative anxiety was sometimes very difficult to determine or predict. The committee also agreed that cases where the person was likely to find it difficult to remain still (either due to physical problems or a longer operation time) were likely to benefit from sedation.
Consideration of health benefits and resource use	No health economic evidence was identified for this review question and economic modelling was not prioritised. The committee discussed the implications of using sedation, noting that it is currently given in 1.5% of all cataract operations in the UK. They agreed that if sedation is given, then an anaesthetist has to be present throughout the procedure. This is due to the risk of patients 'waking up' during the operation and needing additional sedation/anaesthesia. The committee agreed that this would have cost implications, although it was noted that there would be no additional postoperative cost implications as patients recovered quickly from their sedation. It was agreed that such issues would make the availability of sedation to all patients difficult. It noted that, in some centres, a separate anaesthetist-supervised sedation list for cataract surgery was scheduled to make best use of anaesthetist time. The anaesthetic expert advising the committee related experience that the presence of an anaesthetist for these more complex cases can often result in more efficient throughput, more than offsetting the additional costs inherent in the anaesthetist's time.
Quality of evidence	The committee noted that the evidence presented was moderate to high in quality but was limited due to it not addressing the effects of all the sedative drugs in use within UK NHS practice. It also commented that midazolam (alone or in combination with fentanyl) is used in common practice, as is propofol, but no direct evidence was presented from which to help guide the discussion on recommendations. The committee agreed that, since the evidence demonstrated benefit in the general cataract population included in the trials, it was therefore reasonable to assume the benefits would be at least as large or greater in the subpopulations identified as likely to benefit most from sedation.
Other considerations	The committee noted that sometimes sedation may be used as an alternative to general anaesthesia in people where this is deemed to be inappropriate (for example, people with cognitive impairment where there are concerns this may be exacerbated by the use of general anaesthesia).

11.2.7 Recommendations

41. Consider sedation, administered by an experienced ophthalmic anaesthetist, as an adjunct to anaesthesia for people if, for example:

- they have high levels of anxiety
- they have postural or musculoskeletal problems
- surgery is expected to take longer than usual.

11.3 Hyaluronidase as an adjunct to local anaesthesia

11.3.1 Review question

- What is the effectiveness of hyaluronidase as an adjunct to local anaesthesia during cataract surgery?

11.3.2 Introduction

The aim of this review was to determine the effectiveness of hyaluronidase as an adjunct to local anaesthesia during phacoemulsification cataract surgery. The review focused on identifying studies that fulfilled the conditions specified in Table 42. For full details of the review protocol, see Appendix C. The main outcomes for this review were intraoperative pain, patient satisfaction, and volume of anaesthetic needed.

Table 42: PICO criteria – effectiveness of hyaluronidase as an adjunct to local anaesthesia

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery for non-trauma related cataracts and intraocular lens (IOL) implantation
Interventions	Hyaluronidase/hyalase/hyaluronic acid
Comparator	No hyaluronidase/hyalase/hyaluronic acid
Outcomes	• Intraoperative pain • Surgical complication rates • Anaesthetic-related complications • Patient satisfaction • Volume of anaesthetic • Resource use and costs

Papers were excluded if they:

- were not randomised controlled trials
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

11.3.3 Evidence review

In total, 2,676 references were found from a database search for all the review questions looking for randomised controlled trials on anaesthesia, and full-text versions of 18 citations that seemed potentially relevant to this topic were retrieved and screened at full-text. Four RCTs were included (Rowley et al., 2000; Seghipour et al., 2012; Guise et al., 1999 and Schulenburg et al., 2007)

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

The design of included studies is summarised in Table 43, with full details and results found in the evidence tables (see Appendix E).

Table 43: Summary of included studies – effectiveness of hyaluronidase as an adjunct to local anaesthesia

Study & location	Population	Methods
Rowley et al. (2000) UK	150 patients	RCT to investigate the effect of hyaluronidase on the quality of block achieved with sub-Tenon's local anaesthesia.
Seghipour et al. (2012) Iran	42 patients	RCT to investigate the effect of hyaluronidase use on the quality of sub-Tenon's anaesthesia for phacoemulsification
Guise et al. (1999) New Zealand	120 patients	RCT to investigate the effect of hyaluronidase on speed of onset and block quality in sub-Tenon's block
Schulenburg et al. (2007) UK	62 patients	RCT to examine the addition of hyaluronidase on the minimum local anaesthetic volume (MLAV) required for a sub-Tenon's block

11.3.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

11.3.5 Evidence statements

11.3.5.1 Pain

Low-quality evidence from 1 RCT of 120 participants could not differentiate the proportions of those who reported pain on injection of anaesthetic or pain during cataract surgery in those who received anaesthesia with or without the addition of hyaluronidase.

Low-quality evidence from 1 RCT of 150 participants could not detect a difference in reported post-injection pain scores or perioperative pain scores for those who received anaesthesia with or without the addition of hyaluronidase.

11.3.5.2 Patient satisfaction

High-quality evidence from 1 RCT of 42 participants showed that those who received anaesthesia with hyaluronidase were more likely to be satisfied with the anaesthesia.

11.3.5.3 Volume of anaesthetic

Low-quality evidence from 1 RCT of 62 participants showed that those who received anaesthesia with hyaluronidase had a 2.4-fold reduction in median effective local anaesthetic volume needed to achieve a sub-Tenon's block.

11.3.5.4 Health Economic Evidence

No health economic evidence was identified for this review question.

11.3.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that intraoperative pain, patient satisfaction and volume of anaesthetic would all be relevant outcomes.
Trade-off between benefits and harms	The committee agreed that there was evidence of improved patient satisfaction with the addition of hyaluronidase to sub-Tenon's anaesthesia, and that it had no effect on reported injection pain. It agreed that the evidence showed lower levels of anaesthetic were necessary to achieve a sub-Tenon's block when hyaluronidase was added, but noted this did not represent the volume of anaesthetic necessary for adequate pain control, but rather the volume necessary to achieve eye akinesia (an outcome which some surgeons may consider highly desirable, but one which others may not be particularly concerned with). The committee agreed that it was therefore reasonable to make a 'consider' recommendation for the use of hyaluronidase as an adjunct to sub-Tenon's anaesthesia, with a particular comment that its benefit is likely to be greatest when attempting to achieve eye akinesia. The committee also noted that 1 study showed that a high average volume (6.4ml) of anaesthetic was needed in people randomised not to receive hyaluronidase. The injection of this volume into the sub-Tenon's space could elevate the risk of vitreal compression.
Consideration of health benefits and resource use	No health economic evidence was identified for this review question and economic modelling was not prioritised. The committee discussed whether there were likely to be any resource implications from recommending the use of hyaluronidase. It was noted that in the experience of the committee members, and in light of the current low cost of the drug itself (net price £7.60 per 1500-unit ampule, BNF Online 2017), that any recommendation was unlikely to cause a significant resource impact, especially given that the focus would be restricted to those individuals where it is deemed important to achieve eye akinesia.
Quality of evidence	The committee agreed that the overall quality of the evidence was low, but identified no significant negative consequences from the use of hyaluronidase, with the anaesthetist member of the committee informing members that hyaluronidase was used commonly in practice.
Other considerations	No other considerations were identified.

11.3.7 Recommendations

42. Consider hyaluronidase as an adjunct to sub-Tenon's anaesthesia, particularly if trying to stop the eye moving during surgery.

11.4 General anaesthesia

11.4.1 Review question

- In what circumstances should general anaesthesia be considered in phacoemulsification cataract surgery?

11.4.2 Introduction

The aim of this review was to determine in what circumstances general anaesthesia should be considered in phacoemulsification cataract surgery. The review focused on identifying studies that fulfilled the conditions specified in Table 44. For full details of the review protocol, see Appendix C. The main outcomes for this review were indications for general anaesthesia in phacoemulsification cataract surgery.

Table 44: PICO criteria – general anaesthesia

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery for non-trauma related cataracts and intraocular lens (IOL) implantation
Interventions	General anaesthesia
Comparator	Forms of anaesthesia other than general anaesthesia
Outcomes	Indications for general anaesthesia in phacoemulsification cataract surgery

Papers were excluded if they:

- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

11.4.3 Evidence review

In total, 1,059 references were found from a database search for the review question, and full-text versions of 52 citations that seemed potentially relevant to this topic were retrieved. No studies matched the review protocol for this question.

No relevant studies were identified in the update searches undertaken at the end of the guideline development process.

11.4.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

11.4.5 Evidence statements

No evidence was identified for this review question.

11.4.5.1 Health Economic Evidence

No health economic evidence was identified for this review question.

11.4.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that indications for general anaesthesia in cataract surgery would be a relevant outcome but were not surprised that no relevant evidence was identified, as the population of relevant people is not sufficiently large as to make studies easy to conduct.
Trade-off between benefits and harms	The committee recognised the risk/benefits of general anaesthesia (in particular, the risk of exacerbating cognitive decline) and agreed that, although the use of general anaesthetic in cataract surgery was of a shorter duration than the average across all surgical procedures, the patients taking it were much older than average for surgery and so the risk of sequelae may well be close to the average. The committee discussed and agreed that people whose mental capacity limited their ability to undergo surgery, or those exhibiting extreme anxiety, would often be given general anaesthetic for cataract surgery. This was based on clinical experience due to the lack of evidence in this area. Based on clinical experience, the committee agreed that the surgeon would prefer patients to be adequately sedated, but that the use of general anaesthetic would usually be discussed in consultation with the patient and/or their representative(s) before being undertaken. The committee agreed that the points noted above represented current practice in the UK, and therefore it was agreed that no specific recommendations were necessary.
Consideration of health benefits and resource use	No health economic evidence was identified for this review question and economic modelling was not prioritised. It was agreed that there was little reason to believe the current rates of general anaesthesia for cataract surgery were likely to change in the near future, and therefore there were unlikely to be substantial changes in resource use.
Quality of evidence	No evidence was presented which the committee could comment on.
Other considerations	The committee agreed it was important that the need for discussions on general anaesthesia, where relevant, should be included in the patient information section of the guideline.

11.4.7 Recommendations

No recommendations were made for this review question.

12 Preventing and managing complications

Modern phacoemulsification is one of the safest of all surgical procedures with a success rate of 92% or higher. However, complications can potentially occur at any stage of the patient journey. Whilst most are not serious, some complications may compromise visual outcome and negatively impact on patient expectation.

Although it occurs very rarely (around 1 in 1,000 cases) infectious endophthalmitis is considered one of the most serious complications of cataract surgery as, even when treated promptly, it can result in complete loss of vision of the eye. The risk of endophthalmitis can be reduced, but not totally eliminated, by a number of measures.

As it may be significantly associated with other unfavorable outcomes, the other complication which has received much attention in large-scale audits is posterior capsular rupture (PCR). For individual surgeons, having a PCR rate of approximately 2% or less is widely regarded as an indicator of surgical competence , although the probability of PCR for a particular cataract operation may be greatly increased by other factors including co-existing ocular and/or systemic comorbidity. Examples of the former include small pupil size, very dense cataract and poor zonular support.

Therefore, awareness of the likelihood of particular complications in an individual patient's eye, and appropriate risk stratification, is widely acknowledged as an important component of careful preoperative assessment.

The purpose of this chapter is to address how potential complications in cataract surgery are best prevented and, if complications do occur, how these should be managed to optimise the most favourable visual outcome for the patient.

12.1 Interventions to prevent retinal detachment in people with myopia

12.1.1 Review question

- What is the effectiveness of interventions (for example, prophylactic laser surgery) to prevent retinal detachment in people with myopia undergoing cataract surgery?

12.1.2 Introduction

The aim of this review was to determine whether interventions designed to prevent retinal detachment in people with myopia are effective. The review focused on identifying studies that fulfilled the conditions specified in Table 45. For full details of the review protocol, see Appendix C. The main outcome for this review was rates of retinal detachment.

Table 45: PICO criteria – preventing retinal detachment in people with myopia

Population	Adults (18 years and over) with myopia undergoing phacoemulsification cataract surgery with intraocular lens implantation
Interventions	• Prophylactic interventions prior to cataract surgery (not at the time of surgery) • Retinal LASER surgery • Cryotherapy
Comparator	• No prophylactic intervention
Outcomes	• Rates of retinal detachment • Time to event data • Health-related quality of life • Resource use and cost

Papers were excluded if they:

- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- reported studies conducted entirely in non-OECD countries
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

12.1.3 Evidence review

In total, 1,121 references were found from a database search for this review question, and full-text versions of 16 citations that seemed potentially relevant to this topic were retrieved. No studies matched the review protocol for this question.

No relevant studies were identified in the update searches undertaken at the end of the guideline development process.

12.1.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

12.1.5 Evidence statements

No evidence was identified for this review question.

12.1.5.1 Health Economic Evidence

No health economic evidence was identified for this review question.

12.1.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that rates of retinal detachment would be a relevant outcome, but were not surprised that no relevant evidence was identified, as it felt surgeons would be unlikely to undertake research in this area.
Trade-off between benefits and harms	The committee agreed that surgeons would continue to treat as per current practice with possible referral to a vitreoretinal surgeon where possible. The use of cryoprobes was discussed but it was stated that they have inherent dangers such as retinal detachment. The committee agree that, whilst it is possible that there are methods of management that may be more or less effective in people with cataracts than in those without, the lack of evidence made it inappropriate to make specific recommendations.
Consideration of health benefits and resource use	No health economic evidence was identified for this review question and economic modelling was not prioritised. The committee agreed that, since its recommendation did not represent a difference from current practice, it would have no resource implications.
Quality of evidence	No evidence was presented on which the committee could comment.
Other considerations	The committee considered whether the lack of evidence indicated that a research recommendation was appropriate in this area. However, it agreed this did not represent a high priority for research, and that there were other areas of the guideline where it was more important to prioritise research, and therefore no such recommendation was made.

12.1.7 Recommendations

No recommendations were made for this review question.

12.2 Intraoperative pupil size management

12.2.1 Review question

- What is the effectiveness of interventions to increase pupil size to improve visual outcomes and reduce complications during phacoemulsification cataract surgery?

12.2.2 Introduction

The aim of this review was to determine the effectiveness of interventions to increase pupil size to improve visual outcomes and reduce complications during phacoemulsification cataract surgery. The review focussed on identifying studies that fulfilled the conditions specified in Table 46. For full details of the review protocol, see Appendix C. The main outcomes for this review were visual acuity.

Table 46 PICO criteria for interventions to increase pupil size

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery for with intraocular lens (IOL) implantation
Interventions	Interventions to increase pupil size: • Intracameral mydriatics (with or without anaesthesia) • Viscomydriasis with a high-viscosity ophthalmic viscosurgical device (OVD) e.g. sodium hyaluronate • Manual separation: synechiolysis and/or pupillary membranectomy with spatula and forceps • Mechanical pupillary stretching using iris hooks • Sphincter cutting • Use of mechanical pupil dilation/expansion devices
Comparator	• No additional procedure • Each other
Outcomes	• Complications (capsular rupture, haemorrhage) • Postoperative complications (inflammation, distorted pupils) • Visual acuity • Visual function • Resource use and cost

Papers were excluded if they:

- were narrative reviews, case studies/reports, commentaries, editorials/letters or opinion pieces.
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

12.2.2.1 Deviations from protocol

When evidence on this question was discussed, the committee agreed that data on pupil size would be a useful outcome as a marker for the effectiveness of interventions, even though this was not specified in the original protocol. Only 1 included study presented data on pupil size, and these results are included below. No further evidence on pupil size was found on a re-run of the searches for this review question.

12.2.3 Evidence review

In total, 1,186 references were found from a database search for the review question. Full-text versions of 22 citations that seemed potentially relevant to this topic were retrieved and screened. Seven studies were included (5 randomised controlled trials and 2 case-controls; Espindola et al. 2012; Lorente et al. 2012; Moschos et al. 2011; Papaconstantinou et al. 2014; Shigleton et al. 2001 and 2006; Wilczynski et al. 2013).

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

The design of included studies is summarised in Table 47. Full details and results are found in the evidence tables (see Appendix E).

Table 47 Summary of included studies

Study & location	Population	Methods
Espindola et al. (2012) Brazil	78 eyes	RCT to compare the effects and outcomes of 2 viscosurgical devices during phacoemulsification
Lorente et al. (2012) Spain	84 eyes	RCT to evaluate the efficacy of IPH as prophylaxis against intraoperative floppy iris syndrome
Moschos et al. (2011) Greece	77 eyes	RCT to compare Viscoat and Visthesia during phacoemulsification cataract surgery
Papaconstantinou et al. (2014) Greece	44 eyes	RCT to evaluate Viscoat and Visthesia viscosurgical devices in cataract surgery
Shingleton et al. (2001) USA	66 eyes	Case-control study to compare (BCVA) and IOP in eyes that had a foldable IOL implanted with the use of an anterior chamber maintainer (ACM) in 1 eye and Vitrax in the other
Shingleton et al. (2006) USA	240 eyes	Case-control study to determine whether pupil stretching during phacoemulsification affects postoperative best corrected visual acuity compared with results in patients without pupil stretch
Wilczynski et al. (2013) Poland	40 eyes	RCT to evaluate pupils dilated with Malyugin Ring in comparison with manual pupillary stretching hooks.

12.2.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

12.2.5 Evidence statements

12.2.5.1 Best corrected visual acuity – DisCoVisc vs HPMC

Moderate-quality evidence from 1 RCT of 78 eyes could not detect a difference in best corrected visual acuity, 6 months postoperatively, in people given DisCoVisc or HPMC during cataract surgery.

12.2.5.2 Best corrected visual acuity – Viscoat vs VisThesia

Low-quality evidence from 2 RCTs containing 121 eyes could not detect a difference in best corrected visual acuity postoperatively or at 28 days postoperatively in people given Viscoat or VisThesia during cataract surgery.

12.2.5.3 Best corrected visual acuity – intracameral phenylephrine vs balanced salt solution

Low-quality evidence from 1 RCT of 84 eyes could not detect a difference in best corrected visual acuity, 3 months postoperatively, in people given intracameral phenylephrine or balanced salt solution during cataract surgery.

12.2.5.4 Mean best corrected visual acuity (decimal) – anterior chamber maintainer vs Vitrax

Very low-quality evidence from 1 case-control study of 66 eyes could not detect a difference in mean best corrected visual acuity (decimal), 3-6 weeks postoperatively, in people given an anterior chamber maintainer or Vitrax during cataract surgery.

12.2.5.5 Best corrected visual acuity – pupil stretching vs no stretching

Very low-quality evidence from 1 case-control study of 240 eyes could not detect a difference in best corrected visual acuity, 1 year postoperatively, in people given pupil stretching compared with those who were not given pupil stretching during cataract surgery.

12.2.5.6 Best corrected visual acuity – Malyugin Ring vs manual stretching

Moderate-quality evidence from 1 RCT of 40 eyes could not detect a difference in best corrected visual acuity - decimal, 1 month postoperatively, in people given either a Malyugin Ring or manual stretching of the pupil during cataract surgery.

12.2.5.7 Pupil size – intracameral phenylephrine vs balanced salt solution

Moderate-quality evidence from 1 RCT of 84 eyes found that people who were receiving tamsulosin and given intracameral phenylephrine obtained an increased pupil size after hydro-dissection compared with people given balanced saline solution during cataract surgery.

12.2.5.8 Health Economic Evidence

No health economic evidence was identified for this review question.

12.2.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that postoperative complications would be a relevant outcome, but that visual acuity outcomes would be unlikely to help answer this question as in non-randomised studies the aim of these interventions is to ensure people do not achieve worse outcomes than those with normal pupil sizes. Therefore the committee noted that they would not expect to see any benefits when comparing these interventions in people with normal sized pupils. They noted that additional data on pupil size measurements would be of more interest and requested a deviation from the review question protocol to enable this.
Trade-off between benefits and harms	The committee discussed the evidence and raised concerns that the outcomes measured in many trials did not directly answer important clinical questions, as they were often tested in a very broad population, which included people who would not be likely to receive

	these interventions in clinical practice. From the range of evidence presented, the committee agreed that 1 paper was of relevance to show how phenylephrine increased pupil size in people taking tamsulosin and at risk of floppy iris syndrome. From this evidence the committee agreed that although the benefit was seen in patients receiving tamsulosin, they thought the benefit would be generalisable to patients at risk of floppy iris syndrome. Thus a consider recommendation could be made regarding increasing the pupil size of patients at risk of floppy iris syndrome. The committee noted that it would be useful to see evidence on the comparisons of drugs with devices but acknowledged that in most cases the surgeon will try a pharmacological intervention initially and only if this is not successful will revert to a mechanical one.
Consideration of health benefits and resource use	No health economic evidence was identified for this review question, and economic modelling was not prioritised. The committee agreed that although the manual devices used to stretch pupils cost £50-£100, they agreed that their use was justified when compared with the alternative of failing to do the operation or causing intraoperative damage (e.g. PCR) which costs much more to correct. They further stated that such techniques are in common use and there is little alternative.
Quality of evidence	The committee agreed that the overall quality of the evidence was low. They noted that the outcomes reported in the trials often did not help in addressing important clinical questions. The committee requested that the evidence on pupil size be added to the evidence base from the 1 paper in which it was reported.
Other considerations	No other considerations were identified as part of this review question.

12.2.7 Recommendations

43. Consider intracameral phenylephrine to increase pupil size in people at risk of floppy iris syndrome.

12.3 Interventions to reduce the impact of perioperative posterior capsule rupture

12.3.1 Review question

- What is the effectiveness of interventions to reduce the impact of perioperative posterior capsule rupture?

12.3.2 Introduction

The aim of this review was to determine the effectiveness of interventions to reduce the impact of perioperative posterior capsule rupture. The review focused on identifying studies that fulfilled the conditions specified in Table 48. For full details of the review protocol, see Appendix C. The main outcome for this review was visual acuity.

Table 48 PICO inclusion criteria for interventions to reduce the impact of perioperative posterior capsule rupture

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery with intraocular lens implantation with a perioperative posterior capsule rupture.
Interventions	• Anterior vitrectomy + triamcinolone • Timing and type of lens insertion • Early versus late lens removal when lens fallen into back of eye • Anaesthesia
Comparator	• Anterior vitrectomy • Different timings and types • Other timing
Outcomes	• Visual acuity • Visual function • Complications (inflammation and pressure) • Quality of life • Resource use and cost

Papers were excluded if they:

- were narrative reviews, case studies/reports, commentaries, editorials/letters or opinion pieces.
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

12.3.3 Evidence review

In total, 1,984 references were found from a database search for this review question, and the full-text version of 1 citation that seemed potentially relevant to this topic was retrieved. No studies matched the review protocol for this question.

No relevant studies were identified in the update searches undertaken at the end of the guideline development process.

12.3.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

12.3.5 Evidence statements

No evidence was identified for this review question.

12.3.5.1 Health Economic Evidence

No health economic evidence was identified for this review question.

12.3.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that evidence on long-term visual outcomes or rates of complications would be relevant for this review question.
Trade-off between benefits and harms	No evidence was identified for this review question. However, the committee agreed that it was appropriate to make a consensus based recommendation that local areas should have a protocol in place to deal with posterior capsule rupture. They agreed this was necessary as inappropriate short-term management can lead to long term complications, and there were established elements of good quality care that all surgeons could reasonably be expected to follow. The list of items such a protocol should include was decided by informal committee consensus. It was agreed that in the absence of evidence it would not be appropriate to specify details of what the protocol should say, but felt it was appropriate to include a set of minimum elements it should contain. The committee were aware of a number of existing examples of such protocols (for example, one developed by Moorfields Eye Hospital), which both demonstrated the feasibility of developing such a protocol, and provided a template that other centres could work from.
Consideration of health benefits and resource use	No economic evidence was identified for this review question, and economic modelling was not prioritised. The committee agreed that inappropriate management of posterior capsule ruptures had the potentially to lead to serious adverse events down the line, which would be likely to cost considerably more than the cost of appropriate management in the short-term. Therefore, the widespread adoption of appropriate protocols would likely be cost saving.
Quality of evidence	No evidence was identified for this review question.
Other considerations	The committee identified the Royal College of Ophthalmologists as a body that may be appropriate to develop consensus based guidelines on managing posterior capsule ruptures, to serve as a template for local protocols.

12.3.7 Recommendations

44. When dealing with posterior capsule rupture, follow a protocol that covers:

- removing vitreous from the wound and anterior chamber
- minimising traction on the retina
- removing lens fragments in the posterior chamber or vitreous cavity
- removing soft lens matter

- implications for any lens insertion.

12.4 Capsular tension rings

12.4.1 Review question

- What is the effectiveness of capsular tension rings applied during phacoemulsification cataract surgery?

12.4.2 Introduction

The aim of this review was to determine the effectiveness of capsular tension rings applied during phacoemulsification cataract surgery. The review focussed on identifying studies that fulfilled the conditions specified in Table 49. For full details of the review protocol, see Appendix C. The main outcomes for this review were postoperative refraction, visual acuity, postoperative complications.

Table 49 PICO criteria for the effectiveness of capsular tension rings

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery for with intraocular lens (IOL) implantation
Interventions	Capsular tension rings
Comparator	No capsular tension ring
Outcomes	• Postoperative complications (decentration) • Visual acuity • Postoperative refraction • Resource use and costs

Papers were excluded if they:

- were not randomised controlled trials.
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

12.4.3 Evidence review

In total, 1,186 references were found from a database search for the review question. Full-text versions of 17 citations that seemed potentially relevant to this topic were retrieved and screened. Seven randomised controlled trials were included (Alio et al. 2012; Bayraktar et al. 2001; Kocabora et al. (2007); Lee et al. 2002; Mastropasqua et al. 2013; Park et al. 2016 and Rohart et al. 2009). Two of these studies (Bayraktar and Kocabura) contained a population of people with pseudoexfoliation.

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

The design of included studies is summarised in Table 50. Full details and results are found in the evidence tables (see Appendix E).

Table 50 Summary of included studies for the effectiveness of capsular tension rings

Study & location	Population	Methods
Alio et al. (2012) Spain	90 eyes	Rotationally asymmetric multifocal IOL implantation with and without capsular tension ring: refractive and visual outcomes and intraocular optical performance

Study & location	Population	Methods
Bayraktar et al. (2001) Turkey	78 eyes	Capsular tension ring implantation after capsulorhexis in phacoemulsification of cataracts associated with pseudoexfoliation syndrome. Intraoperative complications and early postoperative findings.
Kocabora et al. (2007) Turkey	84 eyes	The preventive effect of capsular tension ring in phacoemulsification of senile cataracts with pseudoexfoliation.
Lee et al. (2002) South Korea	40 eyes	Effect of a capsular tension ring on intraocular lens decentration and tilting after cataract surgery
Mastropasqua et al. (2013) Italy	60 eyes	Multifocal IOL implant with or without capsular tension ring: study of wavefront error and visual performance
Park et al. (2016) South Korea	52 eyes	Effect of co-implantation of a capsular tension ring on clinical outcomes after cataract surgery with monofocal intraocular lens implantation
Rohart et al. (2009) France	40 eyes	Influence of a capsular tension ring on ocular aberrations after cataract surgery: a comparative study

12.4.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

12.4.5 Evidence statements

12.4.5.1 Full population

12.4.5.1.1 Visual acuity

Low-quality evidence from 4 RCTs containing 356 eyes could not detect a clinically meaningful difference in corrected or uncorrected distance or near visual acuity in people given an intraocular lens fitted with or without a capsular tension ring during cataract surgery.

12.4.5.1.2 Cylindrical error

Moderate-quality evidence from 1 RCT containing 52 eyes could not detect a difference in cylindrical error in people given an intraocular lens fitted with or without a capsular tension ring during cataract surgery.

12.4.5.1.3 Corneal oedema

Low-quality evidence from 1 RCT containing 78 eyes could not differentiate the risk of developing postoperative corneal oedema in people given an intraocular lens fitted with or without a capsular tension ring.

12.4.5.1.4 Intraocular lens decentration

Moderate-quality evidence from 1 RCT containing 40 eyes found that people given an intraocular lens fitted with a capsular tension ring had reduced decentration compared with people given an intraocular lens fitted without a capsular tension ring 60 days after cataract surgery.

Moderate-quality evidence from 1 RCT containing 60 eyes could not detect a difference in decentration along the x-axis in people given an intraocular lens fitted with or without a capsular tension ring 360 days after cataract surgery.

High-quality evidence from 1 RCT containing 60 eyes found that people given an intraocular lens fitted with a capsular tension ring had increased decentration along the y-axis compared with people given an intraocular lens fitted without a capsular tension ring 360 days after cataract surgery.

12.4.5.2 People with pseudoexfoliation

Low-quality evidence from 2 RCTs containing 162 eyes found higher rates of IOLs being successfully placed in the bag and lower rates of zonular dehiscence in people with pseudoexfoliation fitted with a capsular tension ring after cataract surgery than those without.

12.4.5.3 Health Economic Evidence

No health economic evidence was identified for this review question.

12.4.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that postoperative refraction, visual acuity and postoperative complications would all be relevant outcomes. The committee also agreed that it would be useful to report successful IOL insertion and adverse event outcomes for people with pseudoexfoliation, as this is a group where the committee believe there is more likely to be a benefit from the use of capsular tension rings. Of the postoperative complication outcomes, the committee agreed that corneal oedema was not as relevant as the others as this is unlikely to be impacted by the use of CTR.
Trade-off between benefits and harms	The committee discussed the evidence and raised concerns that some surgeons may use capsular tension rings as an aid in their surgical technique. They also noted that 1 study used multifocal lenses whereas others used monofocal lenses. The committee agreed that if the surgeon decentres a standard monofocal lens it does not usually impact greatly on the patient's vision but this is much more critical when either multifocal or toric lenses are implanted, due to the greater complexity of the lens. The committee also agreed that the evidence did not show a benefit from using capsular tension rings for general use and formulated a recommendation advising not to use them for routine, uncomplicated cataract surgery. However, the committee noted there were benefits demonstrated in the subpopulation of people with pseudoexfoliation (lower rates of zonular dehiscence and a higher proportion of IOLs implanted successfully). The committee therefore agreed to make a separate recommendation for this sub-population to consider using capsular tension rings during cataract surgery. The committee agreed it could not make a stronger recommendation than this as the studies in this population were short-term, and there was therefore no data available on long-term outcomes.
Consideration of health benefits and resource use	No health economic evidence was identified for this review question and economic modelling was not prioritised. The committee agreed that capsular tension rings are relatively expensive and there would need to be clear benefits to justify their use in routine procedures, and evidence on adverse events in the subpopulation of people with pseudoexfoliation is needed to address the potential cost-

	effectiveness of using capsular tension rings in these cases. However, the evidence suggest that lower rates of zonular dehiscence and higher proportions of successful IOL implantation in this subgroup are associated with capsular tension ring use, and the committee therefore felt that a recommendation to consider their use was appropriate for two reasons. 1 the clinical benefit in this subgroup suggests that although a do not use recommendation was appropriate generally, it did not want to rule out their use in cases of pseudoexfoliation and 2) It would allow further, longer-term evidence to be collated that would enable a thoroughgoing cost-effectiveness analysis of CTRs to be undertaken.
Quality of evidence	The committee agreed that the overall quality of the evidence was reasonable. They were interested in the lower vitrectomy rates reported in patients receiving a capsular tension ring. Vitrectomies have costs and associated complication rates, such that a reduction in vitrectomy rates implies a meaningful gain for patients. The committee also agreed that 0.1mm or less decentration of the lens postoperatively is unlikely to be meaningful. The committee noted that as pseudoexfoliation occurs in around 15% of patients, it would have been helpful to have seen evidence on lens decentration in patients with the condition but accepted that there were no studies reporting this outcome in the required population. The committee formulated a research recommendation in order to answer this, and assess the long-term effectiveness of capsular tension rings in this group.
Other considerations	No other considerations were identified as part of this review question.

12.4.7 Recommendations

45. Do not use capsular tension rings in routine, uncomplicated cataract surgery.

46. Consider using capsular tension rings for people with pseudoexfoliation.

12.4.8 Research recommendations

13. What is the long-term effectiveness of capsular tension rings in people with pseudoexfoliation undergoing cataract surgery?

Why is this important?

Evidence indicates that there are benefits from using capsular tension rings in people with pseudoexfoliation such as lower rates of zonular dehiscence and a higher proportion of IOLs being implanted successfully but these were only measured a short time after surgery. Well conducted randomised controlled trials in this population would help to show whether these benefits continued in the long term and so inform future recommendations on their use.

12.5 Interventions to prevent endophthalmitis

12.5.1 Review question

- What is the effectiveness of prophylactic antiseptics and antibiotics to prevent endophthalmitis after cataract surgery?

12.5.2 Introduction

The aim of this review was to evaluate the effectiveness of the following interventions to prevent endophthalmitis after cataract surgery:

- prophylactic antiseptics (for example, topical iodine)
- prophylactic antibiotics

The review on antibiotics was undertaken by the Cochrane Eyes and Vision Group, in collaboration with the NICE Internal Clinical Guidelines Team. For the purposes of this guideline, papers from the Cochrane review were excluded if they were conducted in non-OECD countries.

The review focused on identifying studies that fulfilled the conditions specified in Table 51. For full details of the review protocol, see Appendix C.

Table 51: PICO inclusion criteria for the effectiveness of prophylactic antiseptics and antibiotics to prevent endophthalmitis

Population	Adults (18 years and over) undergoing any cataract surgery
Comparisons	• Antiseptics (povidone iodine, chlorhexidine, tisept, presept) vs. no antiseptics • Preoperative antibiotics (in theatre, several days before surgery) vs. no preoperative antibiotics • Timing of intraoperative antibiotics (i.e. administered up to the end of the operation e.g. with infusion in the middle of operation, at end of procedure) • Route of administration of intraoperative antibiotics (topical, parenteral, intravitreous, intracameral, subconjunctival, infusion during surgery) with or without postoperative antibiotics vs. no intraoperative antibiotics or different routes vs. each other • Postoperative (early e.g. few days and longer term e.g. ≥1 week) topical and systemic antibiotics vs. no postoperative antibiotics • Different types of postoperative antibiotics vs. each other • Duration and frequency of postoperative antibiotics • Timing of antibiotics i.e. preoperative vs. intraoperative vs. postoperative vs. combinations of timing of administration
Outcomes	• Endophthalmitis rates: verified/confirmed/culture positive (preferred), suspected, any • Adverse effects of treatment • Best corrected distance visual acuity • Resource use and costs

Randomised controlled trials (RCTs) and systematic reviews of RCTs were included if they evaluated antiseptics, pre-, intra-, or postoperative antibiotic prophylaxis for acute endophthalmitis after cataract surgery. Papers were excluded if they:

- were narrative reviews, case studies/reports, case series, reliability studies, diagnostic accuracy studies, non-comparative studies
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- reported studies conducted entirely in non-OECD countries

- were not published in the English language.

For the list of excluded studies with reasons, see Appendix F.

12.5.3 Evidence review

Two separate systematic searches were conducted (see Appendix D) – 1 for prophylactic antiseptics and 1 for prophylactic antibiotics to prevent endophthalmitis after cataract surgery.

Electronic literature searches for RCTs of cataract surgery that evaluated giving prophylactic antiseptics to prevent endophthalmitis identified 356 potentially relevant references. After removing duplicates the references were screened on their titles and abstracts and full papers of 6 references were obtained and reviewed against the inclusion and exclusion criteria in the review protocol (see Appendix C). However, none of these references met the inclusion criteria for this review, for reasons such as not being a randomised-control trial or not reporting an outcome of interest. No references on prophylactic antiseptics were therefore included in this review.

As of 25 October 2012, electronic literature searches for RCTs of cataract surgery that evaluated giving antibiotics shortly before, during, or immediately after surgery to prevent endophthalmitis identified 491 potentially relevant titles and abstracts for this review (Gower 2013). After duplicate independent abstract review, 12 references were assessed at the full-text level, of which 7 were excluded and 5 were included in the review. The 5 references reported 2 studies. A review of references that cited the included studies and the reference lists of included studies identified 1 additional record that was excluded after full-text assessment.

An update search in April 2016 identified 123 new records. The Cochrane information specialist removed 34 duplicate records and the remaining 89 reports were screened. Overall, 84 references were excluded after reading the abstracts and full papers of 5 references were obtained for further assessment. However, none met the eligibility criteria for this review and were therefore excluded.

In total 2 references on prophylactic antibiotics to prevent endophthalmitis after cataract surgery were therefore included in this review.

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

12.5.3.1 Description of included studies

Sobaci et al. (2003) was conducted in Turkey and compared antibiotics (vancomycin and gentamicin) in balanced salt solution (BSS) irrigating infusion fluid with BSS-only irrigating infusion fluid in 644 eyes of 640 participants. All were treated with ofloxacin and diclofenac sodium 4 times on the day before surgery. Povidone iodine was used for antisepsis at the time of surgery and a solution of ofloxacin, dexamethasone and indomethasine was given postoperatively. Follow-up was for 6 weeks after the operation. Since the incidence of endophthalmitis following cataract surgery is low (the study authors reported the rate of postoperative endophthalmitis at their institution was 0.109%) and because only 644 eyes were included in the study (with less than 1 eye expected to be affected), the study lacked sufficient power to detect valid differences between treatments.

ESCRS 2007, conducted at multiple sites throughout Europe and Turkey, implemented a 2-by-2 factorial design to evaluate intracameral cefuroxime injected at the end of surgery and topical levofloxacin given immediately preoperatively (within 1 hour of surgery) and up to 15 minutes following surgery in 16,603 participants. In a factorial design studying 2 drugs or

procedures that are expected to act independently, treatment arms were allocated such that both drugs can be evaluated alone and in combination.

In ESCRS 2007, the 2 interventions studied were intracameral cefuroxime and topical levofloxacin. One group received only intracameral cefuroxime, 1 group received only topical levofloxacin, 1 group received both intracameral cefuroxime and topical levofloxacin, and 1 group received neither intervention. Povidone iodine was used for antisepsis at the time of surgery and topical levofloxacin was given to all participants starting the morning after surgery. Follow-up was for 6 weeks after the operation.

The included studies are summarised in Table 52; full details are found in the evidence tables (see Appendix E).

Table 52 Summary of included studies for the effectiveness of prophylactic antiseptics and antibiotics to prevent endophthalmitis

Study & location	Population	Comparison(s)	Antibiotics or antiseptics	Placebo
ESCRS 2007 Austria, Belgium, Germany, Italy, Poland, Portugal, Spain, Turkey and the UK	16,603 people undergoing phacoemulsification cataract surgery	Intracameral antibiotics vs. topical antibiotics (pre- and postoperative) vs. combined intracameral and topical antibiotics vs. placebo	Intervention #1: intracameral cefuroxime 0.9% (injected into the anterior chamber at the end of surgery) Intervention #2: topical levofloxacin 0.5% (instilled one drop one hour before surgery, one drop half an hour before surgery, and three more drops at 5-minute intervals immediately after surgery) Intervention #3: combined intracameral cefuroxime and topical levofloxacin	Intervention #4: placebo drops (no sham injection was given)
Sobaci et al. 2003 Turkey	644 eyes of 640 people undergoing phacoemulsification cataract surgery	Intraoperative antibiotics vs. no antibiotics	Intervention #1: balanced salt solution (BSS) with antibiotics (20 mg/mL vancomycin and 8 mg/mL gentamicin	Intervention #2: BSS-only irrigating infusion fluid

12.5.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

12.5.5 Evidence statements

12.5.5.1 Endophthalmitis rates

12.5.5.1.1 Culture-proven cases

Low- to moderate-quality evidence from 1 RCT containing 16,603 participants could not detect a clinically meaningful difference in the risk of culture-proven postoperative endophthalmitis at 6 weeks between topical levofloxacin alone and placebo drops, or between eyes treated with intracameral cefuroxime alone and eyes treated with topical

levofloxacin alone, or combined intracameral cefuroxime and topical levofloxacin compared with eyes treated with topical levofloxacin alone.

Very low-quality evidence from 1 RCT containing 640 participants found no meaningful difference in the risk of culture-proven postoperative endophthalmitis at 6 weeks between irrigation with balanced salt solution with vancomycin and gentamicin and balanced salt solution alone.

12.5.5.1.2 Clinically diagnosed cases

High-quality evidence from 1 RCT containing 16,603 participants found that intracameral cefuroxime injections, with or without topical levofloxacin, compared with no prophylaxis is associated with a clinically meaningfully reduced risk of clinically diagnosed postoperative endophthalmitis.

Moderate-quality evidence from 1 RCT containing 16,603 participants found that combined intracameral cefuroxime and topical levofloxacin, compared with topical levofloxacin alone, is associated with a clinically meaningfully reduced risk of clinically diagnosed postoperative endophthalmitis.

12.5.5.2 Best corrected distance visual acuity (BCVA)

No evidence for BCVA was identified.

12.5.5.3 Adverse events

No evidence for adverse events was identified.

12.5.5.4 Health Economic Evidence

No health economic evidence was identified for this review question.

12.5.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that both clinically diagnosed and culture-proven endophthalmitis rates were useful outcomes, and that an effect on either outcome would be meaningful.
Trade-off between benefits and harms	The committee was not surprised that there were no RCT evidence for antiseptics as they are used extensively as part of standard surgical practice to prevent infection (in both cataract and other types of surgery). It may therefore be unethical not to offer people antiseptics or to randomise people to a pure placebo group in research trials. The routine use of antiseptic prophylaxis was also confirmed in the 2 RCTs of antibiotics, where antiseptics were used as prophylaxis at the time of surgery. The committee agreed that, although there is no evidence on the use of antiseptic prophylaxis, a strong ('use') recommendation should still be made due to the widespread practice. It also agreed that, since there was no evidence to suggest antiseptic use should be any different in people with cataract surgery, the use should be in line with standard general surgical practice. For the study by ESCRS, the committee discussed the evidence for both clinically diagnosed and culture-proven endophthalmitis, where significant findings were only seen in the clinically diagnosed endophthalmitis with intracameral cefuroxime and in none of the culture-proven cases. The committee discussed and agreed that clinically diagnosed cases may not always be culture-positive. Examples of possible reasons for this could be that the culture

	techniques used are not sensitive enough or the sample taken is not large enough to have captured an adequate amount of the bacteria to grow on the culture plate. The committee was therefore not concerned about the non-significant results for culture-proven endophthalmitis. The committee agreed that, as a significant reduction in clinically diagnosed endophthalmitis with intracameral cefuroxime was evident in the evidence and from the clinical experience of committee members, intracameral injection is also more comfortable for the patient, a strong ('use') recommendation should be made. However, the committee stressed the importance of providing the correct concentration of intracameral antibiotics to prevent toxicity. Accurate dilution of the drug is therefore essential. The committee therefore agreed that dilution of antibiotics should not take place in theatre, where the risk of errors being made is considerably higher. The antibiotic solution should either be commercially prepared (diluted) or prepared in a designated pharmacy (which may be within the hospital).
Consideration of health benefits and resource use	As antibiotics and antiseptics are commonly used there are not expected to be any significant resource implications from the recommendations made, especially when compared with the significant costs incurred in the treatment of endophthalmitis.
Quality of evidence	The committee agreed that the ESCRS study was well-designed and executed but for the Sobaci et al. (2003) study, the committee had some concern that excluding people where the surgical technique was modified may have excluded people at the highest risk of infection. They also noted the small study sample size in the Sobaci et al. study and agreed that the trial would need to be much larger in order to provide any meaningful evidence. The committee discussed the lack of evidence on postoperative antibiotics, and that this may be due to the fact that they are provided as part of standard good clinical practice in the UK (although there is wide variation in practice around the world). In addition, the committee recognised that patients are invariably receiving other drops (e.g. steroids), which are likely provided in combination with postoperative antibiotic drops and often in a single drop product. For this reason, and in the absence of evidence, the committee agreed that it would be inappropriate to make a recommendation for postoperative antibiotics at this stage but instead it would useful to make a recommendation for future research.
Other consideration	The committee discussed the risk of antibiotic resistance but agreed that the risk is low here because the doses are so low, and none of the commonly used antibiotics are ones that are critical for use in other situations. The committee was therefore not concerned about any antibiotic resistance issues as a result of the recommendations made.

12.5.7 Recommendations

47. Use preoperative antiseptics in line with standard surgical practice.

48. Use intracameral cefuroxime during cataract surgery to prevent endophthalmitis.

49. Use commercially prepared or pharmacy-prepared intracameral antibiotic solutions to prevent dilution errors.

12.5.8 Research recommendation

14. What is the effectiveness of postoperative antibiotic drops to reduce rates of endophthalmitis after cataract surgery?

Why this is important

There is a lack of evidence on postoperative antibiotics to reduce rates of endophthalmitis, which may be because they are provided as part of standard good clinical practice in the UK. In addition, it is recognised that patients are invariably receiving other drops (for example, steroids), which are likely to be offered in combination with postoperative antibiotic drops, and often in a single-drop product. Well-conducted randomised controlled trials of postoperative antibiotics in people having cataract surgery would help add to the evidence base and so inform future recommendations on their use.

12.6 Interventions to prevent cystoid macular oedema

12.6.1 Review question

- What is the effectiveness of prophylactic topical corticosteroids and/or NSAIDs to prevent inflammation and cystoid macular oedema after phacoemulsification cataract surgery?

12.6.2 Introduction

This review was undertaken by the Cochrane Eyes and Vision Group, in collaboration with the NICE Internal Clinical Guidelines Team. For the purposes of this guideline, papers from the Cochrane review were excluded if they were conducted in non-OECD countries, did not use phacoemulsification or compared oral corticosteroids and/or NSAIDs with no treatment or another intervention within the same class.

The aim of this review was to evaluate the effectiveness of prophylactic topical corticosteroids and/or non-steroidal anti-inflammatory drugs (NSAIDs) to prevent inflammation and cystoid macular oedema following phacoemulsification cataract surgery. Studies where no active intervention was given were not included, as these were deemed not to be representative of current practice.

The review focused on identifying studies that fulfilled the conditions specified in Table 53. For full details of the review protocol, see Appendix C.

Table 53: PICO inclusion criteria for the effectiveness of prophylactic topical corticosteroids and/or NSAIDs to prevent inflammation and cystoid macular oedema

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery with intraocular lens implantation
Comparisons	• Combination of corticosteroid and NSAID drops vs. corticosteroid drops • Combination of corticosteroid and NSAID drops vs NSAID drops • Corticosteroid drops vs. NSAID drops • Different dosing (frequency and duration) of postoperative treatment
Outcomes	• Inflammation rates • Cystoid macular oedema (clinically symptomatic, optical coherence tomography-verified) • Best corrected distance visual acuity • Adverse effects of treatment e.g. raised intraocular pressure (steroid-induced glaucoma), allergies (such as sensitivity to preservatives) • Resource use and costs

Randomised controlled trials (RCTs) and systematic reviews of RCTs were included if they compared topical corticosteroids and/or NSAIDs with another relevant intervention. Papers were excluded if they:

- were narrative reviews, case studies/reports, case series, reliability studies, diagnostic accuracy studies, non-comparative studies
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- compared oral corticosteroids and/or NSAIDs with no treatment or another intervention within the same class
- reported studies conducted entirely in non-OECD countries
- were not published in the English language.

12.6.3 Evidence review

A systematic search was conducted (see Appendix D), which identified 928 references. After removing duplicates the references were screened on their titles and abstracts and full papers of 62 references were obtained and reviewed against the inclusion and exclusion criteria in the review protocol (see Appendix C). From examining reference lists of the retrieved studies, 2 additional references were identified as being potentially relevant.

Overall, 46 references were excluded as they did not meet the eligibility criteria, for reasons such as not being a randomised-control design or not assessing an included intervention. A detailed list of excluded studies and reasons for their exclusion is provided in Appendix F. The remaining 18 studies were identified as being relevant and were therefore included in this review.

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

12.6.3.1 Description of included studies

The included studies are summarised in Table 54; full details are found in the evidence tables (see Appendix E). All 18 identified primary studies were randomised controlled trials, 13 comparing NSAIDs plus steroids versus steroids alone, and 6 comparing NSAIDs versus steroids (1 RCT had 3 treatment arms – NSAIDs plus steroids, NSAIDs and steroids).

Table 54 Summary of included studies for the effectiveness of prophylactic topical corticosteroids and/or NSAIDs to prevent inflammation and cystoid macular oedema

Study & location	Population	Comparison(s)	NSAIDS	Steroid
Almeida 2008 Canada	98 people; 106 eyes Average age (years): 72	NSAIDS plus steroids versus steroids	Ketorolac 0.5%	Prednisolone acetate 1%
Almeida 2012 Canada	193 people Average age (years): 72	NSAIDS plus steroids versus steroids	Ketorolac 0.5%, Nepafenac 0.1%	Prednisolone 1%
Asano 2008 Japan	150 people; 150 eyes Average age (years): 66	NSAIDS versus steroids	Diclofenac 0.1%	Betamethasone 0.1%
Cervantes Coste 2009 Mexico	60 people; 60 eyes Average age (years): 72	NSAIDS plus steroids versus steroids	Nepafenac 0.1%	Dexamethasone (combined with tobramycin)
Chatziralli 2011 Greece	145 people; 145 eyes Average age (years): 74	NSAIDS plus steroids versus steroids	Ketorolac 0.5%	Dexamethasone 0.1% (combined with tobramycin 0.3%)
Donnenfeld 2006 USA	100 people Average age (years): 73	NSAIDS plus steroids versus steroids	Ketorolac 0.4%	Prednisolone 1%
Endo 2010 Japan	75 people; 75 eyes Average age (years): 69	NSAIDS versus steroids	Bromfenac	Betamethasone (with fradiomycin sulfate) followed by fluorometholone

Study & location	Population	Comparison(s)	NSAIDS	Steroid
Jung 2015 South Korea	91people; 91 eyes Average age (years): 67	NSAIDS versus steroids	Bromfenac 0.1% Ketorolac 0.4%	Prednisolone acetate 1%
Mathys 2010 USA	84 people; 84 eyes Average age (years): 72	NSAIDS plus steroids versus steroids	Nepafenac 0.1%	Prednisolone 1%
Miyake 2007 Japan	62 people; 62 eyes Average age (years): 66	NSAIDS versus steroids	Diclofenac 0.1%	Fluorometholone 0.1%
Miyake 2011 Japan	60 people; 60 eyes Average age (years): 65	NSAIDS versus steroids	Nepafenac 0.1%	Fluorometholone 0.1%
Miyanaga 2009 Japan	72 people; 72 eyes Average age (years): 72	NSAIDS plus steroids versus steroids/ NSAIDS versus steroids	Bromfenac 0.1%	Betamethasone 0.1%
Moschos 2012 Greece	79 people; 79 eyes Average age (years): 77	NSAIDS plus steroids versus steroids	Diclofenac 0.1%	Dexamethasone 0.1% (combined with chloramphenicol 0.5%)
Wittpenn 2008 USA	546 people; 546 eyes Average age (years): 70	NSAIDS plus steroids versus steroids	Ketorolac 0.4%	Prednisolone 1%
Yavas 2007 Turkey	189 people; 189 eyes Average age (years): 65	NSAIDS plus steroids versus steroids	Indomethacin 0.1%	Prednisolone 1%
Zaczek 2014 Sweden	160 people; 160 eyes Average age (years): 69	NSAIDS plus steroids versus steroids	Nepafenac 0.1%	Dexamethasone 0.1%
Singh 2012 USA	263 people Average age (years): 66 All with diabetic retinopathy	NSAIDS plus steroids versus steroids	Nepafenac 0.1%	Prednisolone acetate
Pollack 2016 Europe, India, Israel New Zealand and the USA	175 people Average age (years): 69 All with diabetic retinopathy	NSAIDs plus steroids versus steroids	Nepafenac 0.1%	Dexamethasone 0.1%

12.6.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

12.6.5 Evidence statements

12.6.5.1 Inflammation

Very low-quality evidence from 5 RCTs containing 346 participants found no meaningful difference between NSAIDs and steroids in controlling postoperative inflammation (measured as flare [photons/ms]) after cataract surgery.

Low quality-evidence from 1 RCT containing 47 participants indicates that, compared with steroids alone, NSAIDs plus steroids are more effective in controlling postoperative inflammation (measured as flare [photons/ms]) after cataract surgery.

Very low-quality evidence from 2 RCTs containing 198 participants found no meaningful difference between NSAIDs plus steroids and steroids alone in the risk of postoperative inflammation (measured as number of events) after cataract surgery.

12.6.5.2 Cystoid macular oedema

Low-quality evidence from 4 RCTs containing 291 participants indicates that, compared with steroids, NSAIDs are associated with a lower risk of cystoid macular oedema after cataract surgery.

Low-quality evidence from 9 RCTs containing 1,388 participants indicates that, compared with steroids alone, NSAIDs plus steroids are associated with a lower risk of cystoid macular oedema after cataract surgery.

12.6.5.2.1 Population with diabetic retinopathy

Moderate-quality evidence from 2 RCTs containing 409 participants with diabetic retinopathy indicates that, compared with steroids alone, NSAIDs plus steroids are associated with a lower risk of cystoid macular oedema after cataract surgery.

12.6.5.3 Best corrected distance visual acuity (BCVA)

Very low-quality evidence from 3 RCTs containing 220 participants found no meaningful difference between NSAIDs and steroids on the improvement of BCVA [logMAR] after cataract surgery.

Very low-quality evidence from 7 RCTs containing 782 participants found no meaningful difference between NSAIDs plus steroids and steroids alone on the improvement of BCVA [logMAR] after cataract surgery.

12.6.5.3.1 Population with diabetic retinopathy

Low-quality evidence from 2 RCTs containing 405 participants with diabetic retinopathy found a lower proportion of people treated with NSAIDs plus steroids lost at least 5 letters of BCVA, compared with those treated with steroids alone.

Very low-quality evidence from 2 RCTs containing 404 participants with diabetic retinopathy found no meaningful difference between NSAIDs plus steroids and steroids alone on the improvement of mean BCVA [letters] after cataract surgery.

12.6.5.4 Poor vision due to cystoid macular oedema (CMO)

Very low-quality evidence from 3 RCTs containing 679 participants found no meaningful difference between NSAIDs plus steroids and steroids alone in the risk of poor vision due to CMO after cataract surgery.

12.6.5.5 Adverse events

Very low-quality evidence from 5 RCTs containing 346 participants found no meaningful difference between NSAIDs and steroids in the risk of adverse events.

Very low-quality evidence from 10 RCT containing 1,467 participants found no meaningful difference between NSAIDs plus steroids and steroids alone in the risk of adverse events.

12.6.5.6 Network meta-analyses

Low-quality evidence from a network meta-analysis of 5 RCTs containing 370 participants found that NSAIDs plus steroids are more effective in controlling postoperative inflammation after cataract surgery compared with steroids alone.

Low-quality evidence from a network meta-analysis of 12 RCTs containing 1,656 participants found that, compared with steroids alone, NSAIDs plus steroids and NSAIDs alone both lower the risk of cystoid macular oedema after cataract surgery.

Low-quality evidence from a network meta-analysis of 9 RCTs containing 979 participants could not differentiate the improvements in BCVA after cataract surgery between people receiving steroids, NSAIDs or NSAIDs plus steroids.

12.6.5.7 Health Economic Evidence

No health economic evidence was identified for this review question.

12.6.6 Evidence to recommendations

Relative value of different outcomes	The committee considered that the measures of postoperative CMO (measured by OCT), visual acuity and inflammation were all important effectiveness outcomes. However, the committee noted that, in the included studies, inflammation was measured using laser flare photometry and because this is not used in current clinical practice, it reduces its relative value in this review.
Trade-off between benefits and harms	The committee noted that the evidence was only available in a low-risk (routine) population and that majority of the studies had excluded the higher-risk population, such as people at high risk of inflammation or those with uveitis, who have a predisposition for CMO. The committee discussed whether the evidence could be generalised and applied to the high-risk population and it agreed that, based on committee members' clinical experience, they would expect to see similar overall relative benefits in both groups (although absolute effects would be greater, owing to higher underlying event rates), despite the lack of evidence in the high-risk group. The committee also discussed the use of topical steroids and NSAIDs in current clinical practice and agreed that both groups of drugs are routinely used in prophylaxis and treatment. In particular, the committee highlighted that NSAIDs with or without steroids are commonly administered to people with diabetes and for treatment of symptomatic CMO, in which setting they have been shown to be effective. However, the committee also acknowledged that some clinicians may worry about prescribing NSAIDs due to side effects such as stinging, burning, and conjunctival hyperaemia which could potentially lead to poor compliance. These types of side effects were also reported in some of the included studies. Discussing the evidence, the committee agreed that, although NSAIDs with or without steroids were shown to be better than steroids alone in reducing the risk of CMO, in people with a low

	preoperative risk of CMO, the effects shown would not be sufficient to justify the routine use of combination NSAID and steroid therapy for all people undergoing cataract surgery, particularly given the low quality of much of the evidence base. Hence, based on the evidence-base and the current clinical practice of providing either topical steroids and/or NSAIDs as prophylaxis to people undergoing cataract surgery, the committee agreed to make a recommendation to offer topical steroids and/or NSAIDs for all people following cataract surgery. The committee discussed whether to make a specific recommendation for the high-risk population. From the knowledge and clinical experience of committee members, combination therapy is commonly used in people who are at higher risk of CMO. The majority of the studies intentionally excluded people who are at high risk, and therefore the only relevant evidence came from populations of people with diabetic retinopathy. The committee agreed that it was reasonable to extrapolate this evidence to other populations at high preoperative risk of CMO, such as people with other retinal disease or uveitis, and therefore a 'consider' recommendation was made for combination therapy in people at high risk of CMO. No evidence was identified on the timing/duration of treatment, and therefore the committee agreed it was not possible to make any recommendations on this topic. The committee also discussed whether to make a recommendation on dosages; however, due to no evidence being available on what the correct/appropriate dosage should be, it agreed not to make any recommendations.
Consideration of health benefits and resource use	The committee noted that, while the resource implications of offering combination treatment over monotherapy were small in any individual case, a recommendation for routine dual therapy in every cataract surgery would amount to a consequential increase in costs. Therefore, the committee agreed this supported its recommendation that combination therapy is not routinely necessary in people at low risk of CMO. In high-risk populations, the extra resources used were felt to be justified, as a significant reduction in rates of CMO would have savings in terms of treatment which would comfortably offset the costs of prophylaxis.
Quality of evidence	The committee discussed that it may be difficult to generalise the evidence to the most common settings in the UK because the majority of the evidence was only available in populations at low preoperative risk for CMO. Nevertheless, the committee agreed that it would expect to see a similar overall relative response in both groups. The committee noted that the evidence presented consisted of comparisons between active treatments, rather than comparisons to no treatment or placebo. However, the agreed that it would be considered unethical not to give some prophylactic treatment, and therefore they agreed this omission did not adversely affect the quality of the evidence base.
Other considerations	The committee noted that ongoing research is taking place in this area (as identified from trial registries as part of the included Cochrane review) and therefore agreed that, at this point, there is no need for any research recommendation.

12.6.7 Recommendations

50. Consider topical steroids in combination with NSAIDs:

- after cataract surgery for people at increased risk of cystoid macular oedema, for example, people with diabetes or uveitis

- to manage cystoid macular oedema.

51. Offer topical steroids and/or non-steroidal anti-inflammatory drugs (NSAIDs) after cataract surgery to prevent inflammation and cystoid macular oedema.

12.7 Managing cystoid macular oedema

12.7.1 Review question

- What is the effectiveness of interventions used to manage cystoid macular oedema following cataract surgery?

12.7.2 Introduction

The aim of this review was to determine the effectiveness of interventions used to manage cystoid macular oedema (CMO) following cataract surgery. The review focussed on identifying studies that fulfilled the conditions specified in Table 55. For full details of the review protocol, see Appendix C. The main outcomes for this review were visual acuity and time to resolution of macular oedema.

Table 55 PICO criteria for managing cystoid macular oedema

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery with intraocular lens (IOL) implantation
Interventions	• NSAIDs • SAIDs • Diamox • Periocular and intraocular steroids • Intraocular Anti-VEGF • Vitrectomy
Comparator	• No intervention • Each other
Outcomes	• Visual acuity • Further surgery (for non-vitrectomy interventions) • Macular thickness • Time to resolution • Adverse events • Quality of life • Resource use and costs

Papers were excluded if they:

- were not randomised controlled trials.
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

12.7.3 Evidence review

In total, 2,539 references were found from a database search for the review question. Full-text versions of 25 citations that seemed potentially relevant to this topic were retrieved and screened. Three randomised controlled trials were included (Heier et al., 2000, Rho, 2003 and Singal et al., 2004).

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

The design of included studies is summarised in Table 56. Full details and results are found in the evidence tables (see Appendix E).

The initial protocol within the Heier et al. (2000) study had an additional treatment arm that was placebo-only. The protocol was not approved in this form. The ethics board believed it was unethical not to treat patients with acute CMO (despite the possibility of spontaneous improvement) because they believed treatment with some form of anti-inflammatory was considered to be standard care.

Table 56 Summary of included studies for managing cystoid macular oedema

Study & location	Population	Methods
Heier (2000) USA	28 patients	RCT to evaluate the efficiency of ketorolac tromethamine, prednisolone acetate and ketorolac and prednisolone combination therapy in the treatment of acute cystoid macular oedema occurring after cataract surgery.
Rho (2003) USA	34 patients	RCT to compare diclofenac sodium solution and ketorolac tromethamine solution in the treatment of cystoid macular oedema after cataract surgery.
Singal (2004) USA	10 patients	RCT to evaluate the use of NSAIDs and steroids in the management of cystoid macular oedema.

12.7.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

12.7.5 Evidence statements

12.7.5.1 Final visual acuity ≥ 20/40

Low-quality evidence from 1 RCT containing 26 participants could not differentiate the proportion of people, who achieved visual acuity equivalent to, or greater than, 20/40, between those who received prednisolone, ketorolac or a combination of ketorolac plus prednisolone, after cataract surgery.

12.7.5.2 Elimination of cystoid macular oedema

Low-quality evidence from 1 RCT containing 34 participants could not differentiate the proportion of people who had their cystoid macular oedema resolved, between those who received ketorolac or diclofenac solution after cataract surgery.

Low-quality evidence from 1 RCT containing 34 participants could not detect a difference in the average time taken, in weeks, for cystoid macular oedema to be resolved, for those people who received ketorolac or diclofenac solution after cataract surgery.

12.7.5.3 Snellen equivalent visual acuity

Low-quality evidence from 1 RCT containing 26 participants could not detect a difference in Snellen equivalent visual acuity, for those people who received ketorolac or ketorolac plus prednisolone after cataract surgery.

12.7.5.4 Health Economic Evidence

No health economic evidence was identified for this review question.

12.7.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that visual acuity and time to resolution of CMO would be relevant outcomes. They also noted that some cases of measurable CMO would spontaneously resolve without the need for further treatment, and this needed to be considered when interpreting the results.
Trade-off between benefits and harms	From their clinical experience, the committee agreed it was likely that combination treatment with both steroids and NSAIDs would be more effective than monotherapy with either alternative. The committee noted that in the trials there was no significant improvement in visual acuity with combination treatment, but the trials contained very small numbers of individuals, with the point estimates in favour of combination treatment. The limited evidence led to the committee to agree that it would be reasonable to make a "consider" recommendation for the use of combination therapy for the treatment of CMO.
Consideration of health benefits and resource use	No health economic evidence was identified for this review question and economic modelling was not prioritised, However, the committee agreed that since only a small proportion of people will develop CMO requiring treatment after cataract surgery, the overall resource implications of this recommendation are likely to be minimal, particularly as in many parts of the country the use of combination treatment is already common practice.
Quality of evidence	The committee agreed that the quality of the evidence was low, highlighting the low number of patients within all the included studies, meaning that it was very unlikely any significant effects would be detected. The committee noted that 1 study reported the average number of people with a final visual acuity ≥ 20/40 as being statistically significant but that the authors did not report their statistical analysis clearly, making it difficult to use in helping to formulate recommendations.
Other considerations	The committee noted that evidence was only found for the use of steroids and NSAIDs, and no evidence was found for the other interventions specified in the protocol. They therefore agreed that further research would be of benefit, leading to the formulation of a research recommendation for the postoperative treatment of patients with CMO.

12.7.7 Recommendations

The recommendations made for this review question are presented in section 12.6.7.

12.7.8 Research recommendations

15. What is the most effective postoperative medical management for cystoid macular oedema?

Why this is important

Although there is evidence for using steroids and non-steroidal anti-inflammatory drugs (NSAIDs) in treating cystoid macular oedema, no evidence has been identified for

interventions such as Diamox, steroidal anti-inflammatory drugs (SAIDs) or intraocular anti-vascular endothelial growth factors (anti-VEGFs). Further randomised controlled trials with increased numbers of participants would be of benefit to the evidence base, which would help lead to the formulation of future recommendations for the postoperative treatment cystoid macular oedema.

12.8 Postoperative eye shields

12.8.1 Review question

- What is the effectiveness of postoperative eye shields to prevent complications after cataract extraction?

12.8.2 Introduction

The aim of this review was to determine the effectiveness of postoperative eye shields to prevent complications after cataract extraction. The review focussed on identifying studies that fulfilled the conditions specified in Table 57. For full details of the review protocol, see Appendix C.

Table 57 PICO inclusion criteria for the effectiveness of postoperative eye shields

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery for with intraocular lens (IOL) implantation
Interventions	• Postoperative eye shields • Length of time with eye shield
Comparator	• No postoperative eye shields • Different lengths of time
Outcomes	• Accidental trauma • Patient satisfaction • Resource use and cost

Papers were excluded if they:

- were narrative reviews, case studies/reports, commentaries, editorials/letters or opinion pieces
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

12.8.3 Evidence review

In total, 1,186 references were found from a database search for this review question, and full-text versions of 8 citations that seemed potentially relevant to this topic were retrieved. No studies matched the review protocol for this question.

No relevant studies were identified in the update searches undertaken at the end of the guideline development process.

12.8.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

12.8.5 Evidence statements

No evidence was identified for this review question.

12.8.5.1 Health Economic Evidence

No health economic evidence was identified for this review question.

12.8.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that outcomes relating to either levels of accidental trauma or patient satisfaction would be relevant, but was not surprised that no relevant evidence was identified. The committee agreed that there was currently a variation in practice between healthcare centres with some routinely giving patients postoperative eye shields and others not. They also noted that when eye shields are given, how long the patients wears them also differed, ranging from 2 days to 6 weeks postoperatively.
Trade-off between benefits and harms	The committee agreed that the use of eye shields came down to individual preference and perception of protection postoperatively. They also noted that the patients may also become influenced by the experience of their partner or friends and family who have previously undergone cataract surgery. The committee agreed that for the majority of people after surgery, there was unlikely to be a practical benefit from eye shields as modern surgical techniques mean the eye is at no greater risk of damage postoperatively than before surgery is undertaken. However, they noted that some people receive psychological reassurance from having an eye shield, and it may help them to return to their normal routine more quickly, as they are less concerned about potentially damaging their eye. As a result of these two opposing perspectives, the committee did not feel able to make either a positive or negative recommendation on the routine use of eye shields. The committee agreed that it was important to make a specific recommendation for people who showed the residual effects of anaesthesia in the eye postoperatively, where there is potential for damage to the eye through accidental trauma. Therefore the committee agreed to recommend that postoperative eye protection be routinely offered to this subgroup.
Consideration of health benefits and resource use	No health economic evidence was identified for this review question and economic modelling was not prioritised. The committee noted that the cost of eye shields is very low (they are available for less than 50p) and therefore the economic impact of any recommendations made was likely to be minimal.
Quality of evidence	No evidence was presented on which the committee could comment.
Other considerations	The committee considered whether the lack of evidence indicated that a research recommendation was appropriate in this area. However, it agreed this did not represent a high priority for research and therefore no such recommendation was made.

12.8.7 Recommendations

52. Offer eye protection for people whose eye shows residual effects of anaesthesia at the time of discharge after cataract surgery.

13 Postoperative assessment

Postoperative follow up for cataract surgery is traditionally recommended to detect possible complications, assess the visual and refractive outcome whilst also considering whether there is a need for surgery on the second eye.

Postoperative assessment may therefore take place outside the cataract operating unit provided that the outcome is communicated back to the unit ensuring access for management of complications is available. This is important to ensure a continuity of care for the patient. Currently there is a variation in practice across the UK as to when and where this takes place and this guideline will help to inform the questions of when this assessment occurs and what aspects are included in the follow up examination to support consistency. In order to prevent possible harms it is important that there is a clear route for postoperative complications to be identified, reported and treated.

Postoperative complications can vary from mild, for example a slight swelling of the eye, to severe, for example endophthalmitis, a rare bacterial infection in the eye, which can lead to blindness. It is therefore important to understand the possible complications of cataract surgery and their incidence in the UK population. This will allow both patients and clinicians to have greater awareness of the risks associated with cataract surgery and as such make better informed choices regarding surgery.

The purpose of this chapter is to consider both the setting and scope of postoperative assessment along with identifying the postoperative complications of cataract surgery.

13.1 Complications of surgery

13.1.1 Review question

- What are the early and late complications of cataract surgery?

13.1.2 Introduction

The aim of this review was to determine the early and late complications of cataract surgery. The review focussed on identifying studies that fulfilled the conditions specified in Table 58. For full details of the review protocol, see Appendix C. The main outcomes for this review were complications and loss of visual function.

Table 58 PICO inclusion criteria for complications of cataract surgery

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery for with intraocular lens (IOL) implantation
Intervention	Not relevant
Comparator	Not relevant
Outcomes	• All complications • Loss of visual acuity • Loss of visual function • Health-related quality of life • Resource use and costs

The review aimed to identify prospective or retrospective cohort studies or case series reporting rates of complications after cataract surgery. Papers were excluded if they:

- were narrative reviews, case studies/reports, commentaries, editorials/letters or opinion pieces
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary populations of people with different eye pathologies
- reported studies conducted entirely in non-OECD countries
- were not published in the English language

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

13.1.3 Evidence review

In total, 8,721 references were found from a database search for the review question. Full-text versions of 30 citations that seemed potentially relevant to this topic were retrieved and screened. Thirteen observational studies were included (6 retrospective cohort, 4 retrospective case series, 2 retrospective chart reviews and 1 retrospective longitudinal study). One further retrospective cohort study was included after a rerun search for this review question (Petousis, 2016).

The design of included studies is summarised in Table 59. Full details and results are found in the evidence tables (see Appendix E). It was not possible to pool the results of individual studies together, and therefore the results for each study are presented individually.

Table 59 Summary of included studies for complications of cataract surgery

Study & location	Population	Methods
Bjerrum et al. USA	202,226 patients	Retrospective cohort to study the risk of pseudophakic retinal detachment after first eye phacoemulsification cataract surgery.

Study & location	Population	Methods
Boberg-Ans et al. Denmark	6,352 patients	Retrospective cohort looking at long-term incidence of rhegmatogenous retinal detachment and survival in a defined population undergoing standardized phacoemulsification surgery
Chu et al. UK	81,984 eyes	Retrospective case series looking at risk factors and incidence of macular oedema after cataract surgery.
Clark et al. Australia	46,258 patients	Retrospective longitudinal study to determine the risk for retinal detachment after phacoemulsification.
Colleaux et al. Canada	13 886 cataract operations	Retrospective chart review looking at effect of prophylactic antibiotics and incision type on the incidence of endophthalmitis after cataract surgery.
Creuzot-Garcher et al. France	6 371 242 eyes	Retrospective cohort determining the incidence of acute postoperative endophthalmitis after cataract surgery.
Day et al. (2015) UK	127,685 patients	Retrospective cohort to describe the outcomes of cataract surgery in the UK.
Day et al. (2016) UK	61 907 eyes	Retrospective case series to investigate time to pseudophakic retinal detachment (RD) after cataract surgery.
Du et al. USA	2 261 779 cataract surgeries	Retrospective cohort to estimate the incidence of infectious endophthalmitis after corneal transplant or cataract surgery.
Freeman et al. Canada	490 690 cataract surgical procedures	Retrospective chart review to estimate annual incidence of endophthalmitis after cataract surgery.
Ianchulev et al. USA	21,484 patients	Retrospective case series to identify safety and effectiveness outcomes of office-based cataract surgery.
Olsen et al. Denmark	7,856 patients	Retrospective cohort to estimate the cumulative risk of retinal detachment (RD) after routine cataract surgery by phacoemulsification.
Petousis et al UK	18,065 patients	Retrospective cohort to identify the risk factors for retinal detachment following cataract surgery.
Venter et al. UK	4,683 patients	Case series to report the effectiveness, patient satisfaction and complication rate with a zonal refractive intraocular lens in a high volume of patients

13.1.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

13.1.5 Evidence statements

13.1.5.1 Retinal detachment

Moderate-quality evidence from 6 retrospective observational studies containing 328,313 participants found rates of retinal detachment post cataract surgery ranged from 0.21% to 0.30% in the UK, and rates from other OECD countries ranging from 0.23% to 0.93%.

Moderate-quality evidence from 2 retrospective observational studies containing 149,169 participants found rates of retinal detachment 90 days postoperatively ranging from 0.03% in the UK to 0.14% in the US.

Moderate-quality evidence from 1 retrospective observational study of 4,683 participants found a rate of retinal detachment during postoperative care after cataract surgery of 0.04% in the UK.

13.1.5.2 Endophthalmitis

Moderate- to low-quality evidence from 2 retrospective observational studies of 3,983,525 eyes and 13,866 people respectively in OECD countries found rates of endophthalmitis post cataract surgery ranging from 0.053% to 0.072%.

Moderate-quality evidence from 2 retrospective observational studies containing 127,685 participants and 490,690 operations respectively found rates of endophthalmitis 90 days postoperatively ranging from 0.03% in the UK to 0.08% in Canada.

Moderate-quality evidence from 1 retrospective observational study of 4683 participants found a rate of endophthalmitis during postoperative care after cataract surgery of 0.1% in the UK.

Low-quality evidence from 1 retrospective cohort study of 2,261,779 operations found rates of endophthalmitis (0.063%) and fungal endophthalmitis (0.002%) 6 weeks postoperatively after cataract surgery.

Low-quality evidence from 1 retrospective cohort study of 2,261,779 operations found rates of endophthalmitis (0.09%) and fungal endophthalmitis (0.005%) 6 months post cataract surgery.

13.1.5.3 Macular oedema

Moderate-quality evidence from 2 retrospective observational studies of 21,484 participants and 81,984 eyes respectively found rates of macular oedema 90 days post cataract surgery ranging from 0.03% in the US to 1.17% in the UK.

Moderate-quality evidence from 1 retrospective case series study of 4,683 participants found rates of macular oedema during postoperative care after cataract surgery of 1.1% in the UK.

Moderate-quality evidence from 1 retrospective case series study of 4,683 participants found rates of macular oedema persisting 1 year post cataract surgery of 0.02% in the UK.

13.1.5.4 Corneal oedema

Moderate-quality evidence from 1 retrospective cohort study of 127,685 participants found rates of corneal oedema post cataract surgery of 0.14% in the UK.

Moderate-quality evidence from 1 retrospective case series study of 21,484 participants found rates of corneal oedema 3 months post cataract surgery of 0.51%.

Moderate-quality evidence from 1 retrospective case series study of 4,683 participants found rates of corneal oedema persisting 1 year post cataract surgery of 0.05% in the UK.

13.1.5.5 Hyphema

Moderate-quality evidence from 1 retrospective case series study of 21,484 participants found rates of hyphema 30 days post cataract surgery of 0.02%.

13.1.5.6 Iritis / Uveitis

Moderate-quality evidence from 1 retrospective case series study of 21,484 participants found rates of iritis / uveitis 1 to 5 months post cataract surgery of 1.54%.

13.1.5.7 Raised intraocular pressure

Moderate-quality evidence from 1 retrospective case series study of 4,683 participants found rates of raised intraocular pressure requiring treatment persisting for 1 year post cataract surgery of 0.01%.

13.1.5.8 Surgical re-intervention

Moderate-quality evidence from 1 retrospective case series study of 4,683 participants found rates of surgical re-intervention during postoperative care after cataract surgery of 0.5%.

Moderate-quality evidence from 1 retrospective case series study of 21,484 participants found rates of surgical re-intervention within 3 months post cataract surgery of 0.61%.

Moderate-quality evidence from 1 retrospective case series study of 21,484 participants found rates of surgical re-intervention within 6 months post cataract surgery of 0.70%.

13.1.5.9 Visual acuity loss

Moderate-quality evidence from 1 retrospective cohort study of 127,685 participants found rates of visual acuity loss post cataract surgery of 1.55% in the UK.

13.1.5.10 Posterior capsule rupture and/or vitreous loss

Moderate-quality evidence from 2 retrospective observational studies of 127,685 and 21,484 participants respectively, found rates of posterior capsule rupture and / or vitreous loss ranging from 1.95% in the UK to 0.95% in the US.

13.1.5.11 Intraoperative complications

Moderate-quality evidence from a retrospective cohort study of 127,685 participants found the following incidence rates of intraoperative complications during cataract surgery in the UK:

- Iris trauma / prolapse 0.50%
- Zonule dialysis 0.48%
- Corneal epithelial abrasion 0.28%
- Endothelial damage / Descemet's tear 0.22%
- Nuclear / epinuclear fragment into vitreous 0.18%
- Lens exchange required / other IOL problems 0.12%
- Phaco burn / wound problems 0.08%
- Hyphaema 0.06%
- Choroidal / suprachoroidal haemorrhage 0.05%

13.1.5.12 Health Economic Evidence

No health economic evidence was identified for this review question.

13.1.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that all the reported complications presented to them would all be relevant outcomes. They also noted that for some complications (e.g. retinal detachment) that could also occur in people who had not had cataract surgery, it was important to know not only absolute rates but also relative risks compared with an age-matched general population.
Trade-off between benefits and harms	The committee agreed that there was lots of relevant evidence. They noted that the reported reduction in retinal detachment rates over time may reflect the increasing familiarity of surgeons with the phacoemulsification procedure. They also highlighted that patients with high myopia were at an increased risk of retinal detachment. The committee discussed the French dataset evidence and agreed that it is likely to include all cataract operations in France over the periods of time reported, and therefore be a representative dataset of all cataract operations. They also noted that the reduction in endophthalmitis incidence rates in France over time may reflect the increasing use of antibiotic prophylaxis, with a similar trend also being observed in the UK. The committee noted that the use of Nd:YAG capsulotomy was also associated with retinal detachments and highlighted a possible causal pathway for later incidence of RD being phacoemulsification procedure, development of cystoid macular oedema, Nd:YAG procedure, leading to retinal detachment. The committee highlighted important uncertainties remaining regarding the risk of intraocular haemorrhage, with particular interest in how anticoagulation treatment affects the risk of intraocular haemorrhage and how uncontrolled hypertension affects the risk of intraocular haemorrhage. They further agreed that haemorrhage and endophthalmitis were the most critical complications in causing blindness after cataract surgery, although it was noted that retinal detachment can cause a permanent loss of sight. The committee noted that when informing patients for consent to surgery, they generally use the headline figures of 1-2/100 chance of making sight worse or not better, 1/1,000 chance of requiring additional surgery and a 1/10,000 chance of losing all sight.
Consideration of health benefits and resource use	No health economic evidence was identified for this review question but it was noted that much of the evidence presented on both absolute and relative risks of events would be of use in the development of the economic model.
Quality of evidence	The committee agreed that the overall quality of the evidence was moderate and from a wide variety of sources. They also noted that whilst the UK cataract dataset is still relatively new, if funding is continued it should, in the future, be able to provide data on the long-term risks of a wide variety of complications in the UK. The committee noted that a number of the included studies were retrospective cohorts, but agreed that as these studies tended to include all cataract operations conducted in the area over the study period, there were unlikely to be serious risk of bias concerns caused by them being retrospective.
Other considerations	Whilst the committee did not make any specific recommendations based on the evidence presented in isolation, they noted it would form an important part of the discussions around both patient information and postoperative assessment, and the numbers would be used as part of parameterisation of the risks of adverse events in the economic model produced for this guideline.

13.1.7 Recommendations

No recommendations were made for this review question.

13.1.8 Research recommendations

16. What is the risk of postoperative retinal detachment in people with high myopia?

Why is this important?

Although it is thought that people with high myopia are at an increased risk of retinal detachment following cataract surgery, there is currently a lack of evidence to support this. This is turn makes it difficult to determine the importance of interventions to prevent retinal detachment in people with high myopia. Well conducted prospective cohort studies would help to build the evidence base in this area of research and so help to inform future recommendations for this population having cataract surgery.

13.2 Details of postoperative assessment

13.2.1 Review questions

- What should the postoperative assessment include?
- Who and in what setting should carry out the postoperative assessment?
- What issues should be considered when organising postoperative care?
- What is the appropriate time to assess outcomes in the postoperative period?
- If the postoperative assessment and care are undertaken outside of the hospital, how should outcomes between surgical units and these providers be effectively communicated?

13.2.2 Introduction

The aim of this review was to determine the appropriate postoperative follow-up care for people undergoing phacoemulsification cataract surgery.

The review focused on identifying studies that fulfilled the conditions specified in Table 60. For full details of the review protocols, see Appendix C.

Table 60: PICO inclusion criteria for postoperative assessment and care

Population	Adults (18 years and over) undergoing phacoemulsification cataract surgery with intraocular implantation
Information needs	• Postoperative follow-up care
Outcomes	• Content in postoperative assessment • Investigations performed • Further interventions – re referral rates • Additional medications prescribed • Delays in diagnosis and treatment • Planned preoperatively at pre-assessment • Stable visual outcome • Resource use and cost

Qualitative surveys or interviews were considered to be the most appropriate study designs to derive information on postoperative follow-up care following phacoemulsification cataract surgery. In a post-hoc deviation to the protocol, RCT evidence was also considered as no relevant qualitative studies were identified. Papers were excluded if they:

- were narrative reviews, commentaries, editorials/letters, opinion pieces or case studies/reports
- collected data using qualitative methods but analysed/presented the data using only quantitative methods
- included animals, healthy eyes, other ocular conditions besides cataracts or mixed primary population of people with different eye pathologies.
- were not published in the English language.

For flow charts of study inclusion and exclusion, see Appendix K. For the list of excluded studies with reasons, see Appendix F.

13.2.3 Evidence review

An overarching systematic search was conducted to inform the review questions on details of postoperative assessment (see appendix D), which identified 2,407 references. The references were screened on their titles and abstracts and full papers of 9 references were

obtained and reviewed against the inclusion and exclusion criteria in the review protocols (see Appendix C).

Overall, 5 studies were excluded as they did not meet the eligibility criteria, for reasons such as not being a qualitative or randomised-controlled design. Of the remaining 4 studies that did meet the eligibility criteria, 3 were RCTs and 1 was a systematic review and meta-analysis. However, all 3 of the relevant RCTs were already included in the relevant systematic review and meta-analysis identified from the search strategy. Therefore, in total, only 1 systematic review and meta-analysis was included in this review.

No additional relevant studies were identified in the update searches undertaken at the end of the guideline development process.

13.2.3.1 Description of included studies

A systematic review and meta-analysis (Kessel et al., 2015) examined whether first-day postoperative examination after uneventful cataract surgery in low-risk patients can be omitted without compromising patient safety. The review identified 3 RCTs that compared patients seen either on the first postoperative day (n=2 studies) or 2 hours after surgery (n=1 study) with those reviewed at 2 weeks. In total, 886 participants were included in the 3 studies and the mean age ranged from 74 to 76 years. The 3 studies were conducted in Greece, United Kingdom and Ireland, respectively. Full details of the included systematic review and meta-analysis is found in the evidence tables (see Appendix E).

13.2.4 Health economic evidence

A literature search was conducted jointly for all review questions in this guideline by applying standard health economic filters to a clinical search for cataracts (see Appendix D). A total of 4,306 references was retrieved, of which 0 were retained for this review question. Health economic modelling was not prioritised for this review question.

13.2.5 Evidence statements

13.2.5.1 Postoperative complications

Very low-to low- quality evidence from 3 RCTs containing 886 participants found that deferred-review is associated with a lower risk, compared with first postoperative day review group, for encountering postoperative complications following cataract surgery but found no meaningful difference between the groups in the risk of serious complications (defined as endophthalmitis, wound leak, or iris prolapse).

13.2.5.2 Number of unscheduled visits

Very low-quality evidence from 3 RCTs containing 886 participants found no meaningful difference in the number of unscheduled visits between discharge and the 2-week postoperative review between the deferred-review group and the first postoperative day review group. Patient reassurance, eye drop toxicity, and corneal abrasion were reported to be the main reasons for unscheduled visits.

13.2.5.3 Postoperative corrected distance visual acuity

Low-quality evidence from 3 RCTs containing 886 participants found no meaningful difference in postoperative visual acuity (logMAR) between the deferred-review group and the first postoperative day review group.

13.2.5.4 Health Economic Evidence

No health economic evidence was identified for this review question.

13.2.6 Evidence to recommendations

Relative value of different outcomes	The committee agreed that the outcomes noted in the protocol were relevant but acknowledged that there was little evidence available to comment on. In particular, the lack of qualitative data on patient experiences of the postoperative pathway meant the committee agreed that the recommendations made would need to be general, and could not cover the full range of individual patient experiences due to a lack of evidence.
Trade-off between benefits and harms	Due to the lack of evidence to fully answer the questions the committee discussed current practice for postoperative care of patients. They agreed that current practice was not to check postoperatively on day 1 following surgery and that generally both a nurse led telephone helpline was utilised and patients told to ring in if they have any issues. They agreed the RCT evidence identified supported this approach as appropriate, and that no evidence had been identified to justify the costs of routine in-person first-day review in people after uncomplicated cataract surgery. The committee therefore agreed a 'do not' recommendation was appropriate in this context. However, the committee agreed that, to prevent possible harms from this approach, it was crucial that there was a clear route for postoperative complications to be reported/identified, and that people should get prompt access to specialist ophthalmology services when these complications did occur. It was agreed that this should be the responsibility of service providers to ensure that such policies/processes are in place at the local level. The committee agreed that clinicians needed to see the patients at some stage postoperatively but there was no evidence of when this should take place. They highlighted the variation in practice with some centres seeing patients 1 week postoperatively whilst others waiting 2 to 4 weeks before discharging patients. In the absence of evidence, the committee agreed it would not be appropriate to make any specific recommendations around timescales for review. The committee noted that as complications such as CMO generally present 6-8 weeks postoperatively and PCO years after surgery that these fall outside of any reasonable follow up timeframe. However it was agreed that if they occurred the patient would be referred back for treatment. The committee agreed the need for a minimum dataset of information which should be gathered at the postoperative visit and that this should include 1. Outcome data, 2. Changes to routine treatment and 3. Second eye surgery listing if required. The committee again noted that there was much variation in practice across the country, but agreed that these represented a basic minimum standard that should always be followed. The committee also noted that the measurement of visual function and quality of life data would be useful, to help assess the benefits of surgery, but agreed that the evidence presented did not enable them to specify one tool as being more appropriate than any other for this purpose. Finally, the committee agreed there were 2 key points in the process where information needed to be provided to the person undergoing surgery. The first is the day of surgery itself, and should include what to expect and who to contact if problems occur. The second point is at the first postoperative visit, where people should be reminded of the expected long term trajectory and who to contact if there are

	problems and given information about when and how to get spectacles they may need.
Consideration of health benefits and resource use	No health economic evidence was identified for this review question, and health economic modelling was not prioritised. The committee agreed that the recommendation to avoid first-day in-person review for people with uncomplicated cataracts surgery would be cost-saving in any areas where this is still undertaken, and that the other recommendations made represented current good practice and should therefore not involve a substantial resource impact.
Quality of evidence	The committee agreed that the overall quality of the evidence was low, mainly due to the lack of masking and a lack of precision in the effect estimates, but that the findings did concur with current practice in the UK.
Other considerations	The committee also considered the evidence on patient information needs identified in section 5.1 when discussing this review question. They agreed that the recommendations made around patient information needs were consistent with the themes identified from that evidence.

13.2.7 Recommendations

53. Commissioners and service providers should ensure that the following are in place:

- Processes that identify complications after surgery and ensure that there is prompt access to specialist ophthalmology services.
- Processes to ensure that the postoperative section of the UK Minimum Cataract Dataset for National Audit is collected and has been entered into an electronic dataset.
- Arrangements so that healthcare professionals discuss second-eye cataract surgery with people who have a cataract in their non-operated eye.

54. Consider collecting patient visual function and quality of life data for entry into an electronic dataset.

55. Do not offer in-person first-day review to people after uncomplicated cataract surgery.

56. At the first appointment after cataract surgery, give people information about:

- eye drops
- what to do if their vision changes
- who to contact if they have concerns or queries
- when it is appropriate to get new spectacles and how to do so
- second-eye cataract surgery if there is a cataract in the non-operated eye
- arrangements for managing ocular comorbidities.

14 Glossary

Glossary of terms used in this guideline	
Anisometropia	Vision imbalance where the eyes naturally focus at different distances.
Bilateral simultaneous cataract surgery	Surgery is undertaken to remove cataracts in both eyes during a single operation or on the same day.
Brunescent cataract	An advanced cataract that is brown in its appearance and has become opaque.
Corneal refractive surgery	Surgical remodelling of the cornea (the outer structure of the eye) to improve how well the eye can focus on objects.
Corneal topography	A non-invasive medical imaging technique for mapping the surface curvature of the cornea (the outer structure of the eye).
Cystoid macular oedema	Fluid and protein deposits collect on or under the macula of the eye (a central area of the retina) and causes it to thicken and swell.
Eye akinesia	A term for when the eye is incapable of moving (short term paralysis of the muscles)
Floppy iris syndrome	A surgical complication characterised by the iris flopping around in the fluid of the eye making cataract extraction more difficult.
Glistenings	A sparkling of light in the visual field.
Keratometry	A process which is used to measure the curvature of the cornea, particularly for assessing levels of astigmatism
Limbal-relaxing incisions	Small cuts in the limbus (the border of the cornea and sclera – the white of the eye), which allows the cornea to become more rounded when it heals.
Mesopic light levels	Low but not quite dark lighting conditions, for example the level of light at night in an area with streetlights.
Monovision	Wearing one contact lens with focuses that eye for distance vision, and a second that focuses the other eye for near vision.
On-axis surgery	A full thickness corneal incision (cut) which flattens the cornea to reduce pre-existing astigmatism (blurred or distorted vision)
Phacoemulsification	Cataract surgery in which the eye's internal lens is broken up using ultrasound before being aspirated (removed by suction) from the eye.
Photopic light levels	Well-lit lighting conditions.
Posterior capsule opacification	A thickening of the back (posterior) of the lens capsule which holds the artificial lens in place. This thickening of the capsule causes vision to become cloudy.
Posterior capsule rupture	A break or tear in the back of the lens capsule which holds the artificial lens in place.
Pseudoexfoliation	An aging–related disease which is characterized by the accumulation of microscopic granular protein fibres, which can lead to a build-up of pressure in the eye.
Refractive implications	How well the eye can focus on objects after surgery and lens insertion.
Retinal detachment	Where the retina separates from the back of the eye.
Snellen Chart	An eyechart commonly used to measure a person's visual acuity. It consist of a series of letters of decreasing size viewed at a distance of 6 metres. Normally a Snellen Chart has one large letter at the top down to a row of very small letters at the bottom. Although it is beginning to be superseded by similar but more reproducible and scientifically valid charts, it is still in common use in clinical practice and is the chart most people will have been asked to read when having their eyes and vision tested.

Glossary of terms used in this guideline	
Suprachorodial haemorrhage	An accumulation of blood within the space between the sclera (white part of the eye) and the choroid (layer in the eye which contains large numbers of blood vessels).
Visual acuity	The clarity and sharpness with which objects are seen, in particular the ability to see fine details.
Zonular dehiscence	Surgical complication where the wound ruptures along a surgical incision in the eye.

4694