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Cataract in the Adult Eye Preferred Practice Pattern®

CATARACT AND ANTERIOR SEGMENT PREFERRED PRACTICE PATTERN® DEVELOPMENT PROCESS AND PARTICIPANTS

The **Cataract and Anterior Segment Preferred Practice Pattern® Panel** members wrote the Cataract in the Adult Eye Preferred Practice Pattern® guidelines (PPP). The PPP Panel members discussed and reviewed successive drafts of the document, meeting in person twice and conducting other review by e-mail discussion, to develop a consensus over the final version of the document.

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We thank our partners, the Cochrane Eyes and Vision US Satellite (CEV@US), for identifying reliable systematic reviews that we cite and discuss in support of the PPP recommendations.

The **Preferred Practice Patterns Committee** members reviewed and discussed the document during a meeting in June 2021. The document was edited in response to the discussion and comments.

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The Cataract in the Adult Eye Preferred Practice Pattern was then sent for review to additional internal and external groups and individuals in June 2021. All those who returned comments were required to provide disclosure of relevant relationships with industry to have their comments considered (indicated with an asterisk below). Members of the Cataract and Anterior Segment Preferred Practice Pattern Panel reviewed and discussed these comments and determined revisions to the document.

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In compliance with the Council of Medical Specialty Societies' Code for Interactions with Companies (available at https://cmss.org/code-signers-pdf/), relevant relationships with industry are listed. The Academy has Relationship with Industry Procedures to comply with the Code (available at www.aao.org/about-preferred-practice-patterns). A majority (78%) of the members of the Cataract and Anterior Segment Preferred Practice Pattern Panel 2020–2021 had no related financial relationship to disclose.

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The disclosures of relevant relationships to industry of other reviewers of the document from January to October 2021 are available online at www.aao.org/ppp.

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OBJECTIVES OF PREFERRED PRACTICE PATTERN® GUIDELINES

As a service to its members and the public, the American Academy of Ophthalmology has developed a series of Preferred Practice Pattern® guidelines that **identify characteristics and components of quality eye care.** Appendix 1 describes the core criteria of quality eye care.

The Preferred Practice Pattern® guidelines are based on the best available scientific data as interpreted by panels of knowledgeable health professionals. In some instances, such as when results of carefully conducted clinical trials are available, the data are particularly persuasive and provide clear guidance. In other instances, the panels have to rely on their collective judgment and evaluation of available evidence.

These documents provide guidance for the pattern of practice, not for the care of a particular individual. While they should generally meet the needs of most patients, they cannot possibly best meet the needs of all patients. Adherence to these PPPs will not ensure a successful outcome in every situation. These practice patterns should not be deemed inclusive of all proper methods of care or exclusive of other methods of care reasonably directed at obtaining the best results. It may be necessary to approach different patients' needs in different ways. The physician must make the ultimate judgment about the propriety of the care of a particular patient in light of all of the circumstances presented by that patient. The American Academy of Ophthalmology is available to assist members in resolving ethical dilemmas that arise in the course of ophthalmic practice.

Preferred Practice Pattern® guidelines are not medical standards to be adhered to in all individual situations. The Academy specifically disclaims any and all liability for injury or other damages of any kind, from negligence or otherwise, for any and all claims that may arise out of the use of any recommendations or other information contained herein.

References to certain drugs, instruments, and other products are made for illustrative purposes only and are not intended to constitute an endorsement of such. Such material may include information on applications that are not considered community standard, that reflect indications not included in approved U.S. Food and Drug Administration (FDA) labeling, or that are approved for use only in restricted research settings. The FDA has stated that it is the responsibility of the physician to determine the FDA status of each drug or device he or she wishes to use, and to use them with appropriate patient consent in compliance with applicable law.

Innovation in medicine is essential to ensure the future health of the American public, and the Academy encourages the development of new diagnostic and therapeutic methods that will improve eye care. It is essential to recognize that true medical excellence is achieved only when the patients' needs are the foremost consideration.

All Preferred Practice Pattern® guidelines are reviewed by their parent panel annually or earlier if developments warrant and updated accordingly. To ensure that all PPPs are current, each is valid for 5 years from the "approved by" date unless superseded by a revision. Preferred Practice Pattern guidelines are funded by the Academy without commercial support. Authors and reviewers of PPPs are volunteers and do not receive any financial compensation for their contributions to the documents. The PPPs are externally reviewed by experts and stakeholders, including consumer representatives, before publication. The PPPs are developed in compliance with the Council of Medical Specialty Societies' Code for Interactions with Companies. The Academy has Relationship with Industry Procedures (available at www.aao.org/about-preferred-practice-patterns) to comply with the Code.

Appendix 2 contains the International Statistical Classification of Diseases and Related Health Problems (ICD) codes for the disease entities that this PPP covers. The intended users of the Cataract in the Adult Eye PPP are ophthalmologists.

METHODS AND KEY TO RATINGS

Preferred Practice Pattern guidelines should be clinically relevant and specific enough to provide useful information to practitioners. Where evidence exists to support a recommendation for care, the recommendation should be given an explicit rating that shows the strength of evidence. To accomplish these aims, methods from the Scottish Intercollegiate Guideline Network[1] (SIGN) and the Grading of Recommendations Assessment, Development and Evaluation[2] (GRADE) group are used. GRADE is a systematic approach to grading the strength of the total body of evidence that is available to support recommendations on a specific clinical management issue. Organizations that have adopted GRADE include SIGN, the World Health Organization, the Agency for Healthcare Research and Policy, and the American College of Physicians.[3]

◆ All studies used to form a recommendation for care are graded for strength of evidence individually, and that grade is listed with the study citation.

◆ To rate individual studies, a scale based on SIGN[1] is used. The definitions and levels of evidence to rate individual studies are as follows:

I++	High-quality meta-analyses, systematic reviews of randomized controlled trials (RCTs), or RCTs with a very low risk of bias
I+	Well-conducted meta-analyses, systematic reviews of RCTs, or RCTs with a low risk of bias
I-	Meta-analyses, systematic reviews of RCTs, or RCTs with a high risk of bias
II++	High-quality systematic reviews of case-control or cohort studies
	High-quality case-control or cohort studies with a very low risk of confounding or bias and a high probability that the relationship is causal
II+	Well-conducted case-control or cohort studies with a low risk of confounding or bias and a moderate probability that the relationship is causal
II-	Case-control or cohort studies with a high risk of confounding or bias and a significant risk that the relationship is not causal
III	Nonanalytic studies (e.g., case reports, case series)

◆ Recommendations for care are formed based on the body of the evidence. The body of evidence quality ratings are defined by GRADE[2] as follows:

Good quality	Further research is very unlikely to change our confidence in the estimate of effect
Moderate quality	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate
Insufficient quality	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate
	Any estimate of effect is very uncertain

◆ Key recommendations for care are defined by GRADE[2] as follows:

Strong recommendation	Used when the desirable effects of an intervention clearly outweigh the undesirable effects or clearly do not
Discretionary recommendation	Used when the trade-offs are less certain—either because of low-quality evidence or because evidence suggests that desirable and undesirable effects are closely balanced

◆ The Highlighted Findings and Recommendations for Care section lists points determined by the PPP Panel to be of particular importance to vision and quality of life outcomes.

◆ All recommendations for care in this PPP were rated using the system described above. Ratings are embedded throughout the PPP main text in italics.

◆ Literature searches to update the PPP were undertaken in March 2020 and January 2021 in the PubMed database. Complete details of the literature searches are available in Appendix 5.

HIGHLIGHTED FINDINGS AND RECOMMENDATIONS FOR CARE

Symptomatic cataract is a surgical disorder. Dietary intake and nutritional supplements have demonstrated minimal effect on the prevention or treatment of cataract.

Most cataract surgery in the United States is performed by small-incision phacoemulsification with foldable intraocular lens (IOL) implantation on an outpatient basis.

Refractive cataract surgery, including astigmatism management, intraoperative refractive guidance, and specialty IOL implantation, has the potential to reduce a patient's dependence on eyeglasses or contact lenses for distance, intermediate, and near vision.

Femtosecond laser-assisted cataract surgery (FLACS) increases the circularity and centration of the capsulorrhexis and the precision of the corneal incisions. It may also reduce the amount of ultrasonic energy required to remove a cataract. However, the technology is not yet cost-effective, and the overall risk profile and refractive outcomes have not been shown to be superior to that of standard phacoemulsification.

Topical nonsteroidal anti-inflammatory drugs (NSAIDs) reduce the incidence of early postoperative cystoid macular edema (CME), but a long-term benefit has not been demonstrated.

There is substantial evidence that intracameral antibiotic administration reduces the risk of postoperative bacterial endophthalmitis. Increasing evidence also suggests that topically applied antibiotics do not add to the benefit of intracameral injection.

Minimally invasive glaucoma surgery can enhance the intraocular pressure-lowering effects of cataract surgery in some patients with mild to moderate glaucoma.

INTRODUCTION

DISEASE DEFINITION

A cataract is a degradation of the optical quality of the crystalline lens that affects vision. Most cataract development is related to aging, and it can occur in one or both eyes.

PATIENT POPULATION

Adults (18 years old and older) with cataracts.

CLINICAL OBJECTIVES

- Identify the presence and characteristics of a cataract.
- Assess the impact of cataract on a patient's visual status and function as well as the effect on quality of life.
- Educate the patient about the natural history of cataract and its impact on vision and functional activity. Explain the benefits and risks of surgery and other treatment alternatives to enable the patient to make an informed decision about treatment options.
- Explain advantages and disadvantages of intraocular lens (IOL) options, including astigmatic, multifocal, extended depth of focus, accommodating, postoperatively power adjustable, and monovision IOL alternatives, to reduce the patient's need for spectacles or contact lenses after surgery.
- Identify any ocular comorbidities, high-risk ocular features, or systemic issues that could impact the performance and outcomes of surgery.
- Establish criteria for a successful treatment outcome with the patient, including working distance(s) and potential limitations in visual outcome(s).
- Discuss potential postoperative refractive options, including bilateral emmetropia, bilateral myopia, and monovision, as well as the management of any anisometropia between surgical procedures.
- Perform cataract surgery when surgery will result in enhanced patient function and when the informed patient elects this option. Timing of surgery should be based on what is mutually agreeable between the patient and surgeon.
- Perform surgery when indicated for improved visualization and management of coexisting ocular disease, such as glaucoma, macular degeneration, or diabetic retinopathy.
- Provide appropriate postoperative care, visual rehabilitation, and treatment of any complications, such as elevated intraocular pressure (IOP) or corneal edema.
- Improve patient safety by reducing the risk of traffic accidents, falls, and fractures.

BACKGROUND

PREVALENCE

Cataract is the leading cause of blindness worldwide.[4] The risk of cataract increases with each decade of life starting around age 40.[5] Cataract is the leading cause of visual impairment among Americans of all studied ethnic and racial backgrounds.[6, 7] In the United States, the number of people with cataract is forecasted to double from 24.4 million to about 50 million by the year 2050.[5]

There are several different types of cataracts that can be categorized according to which part of the lens becomes opaque. Each type has its own anatomical location, pathology, and risk factors for development. The different types can exist separately or in various combinations. Several systems are available to classify and grade lens opacities,[8-12] but variations in grading systems make it difficult to compare prevalence rates between studies.[13]

The three most common types of cataracts are nuclear, cortical, and posterior subcapsular. Less common are anterior subcapsular, anterior polar, and posterior polar cataracts. Nuclear cataract consists of a central opacification or discoloration of the lens that interferes with visual function. There are different types of nuclear cataract: brunescent, opalescent, or both.[14] Nuclear cataract tends to progress slowly and affect distance vision more than near vision.

Cortical cataract can be central or peripheral. It can take the appearance of opaque spokes or oil droplets. Patients with cortical cataract commonly complain of glare. When the entire cortex becomes white and opaque, the cataract is referred to as a mature cortical cataract.

Posterior subcapsular cataract (PSC), located just inside the posterior lens capsule, can cause substantial visual impairment if it involves the axial region of the lens. Patients with PSC often have glare symptoms and poor vision in bright light. Their near vision is typically more affected than distance due to miosis with near accommodation. In young patients, PSC is more common than nuclear and cortical cataract.

Three population-based studies found that cataract surgery was most frequently performed when PSC was a component of the cataract.[15-17] In a study of an older population undergoing cataract surgery (mean age 79 years), the nuclear type was most frequently encountered.[18]

RISK FACTORS

Non-modifiable risk factors for cataract formation include increasing age,[19-25] female gender,[6, 18, 20, 26, 27] and family history.[18, 28-34] Numerous risk factors have been linked with cataract development, the most common of which are listed in Table 1.

Most studies on risk factors are observational and strongly suggest an association with cataract formation, but they fail to prove causation.[30, 35]

TABLE 1   FACTORS ASSOCIATED WITH INCREASED RISK OF CATARACT DEVELOPMENT*

Cataract Type	Associated Risk Factors
Cortical	Diabetes[19, 20, 31, 32, 36-40]
	Family history[20, 41-45]
	Hypertension[19, 39, 46, 47]
	Ionizing radiation (low and high dose)[48]
	Myopia (>1 D)[32, 49, 50]
	Obesity[33, 34, 39]
	Systemic corticosteroid use[51]
	Trauma[52]
	Ultraviolet-B light exposure[21, 32, 41, 53, 54]
Nuclear	Diabetes[32, 39]
	Family history[41, 44, 55, 56]
	Hypertension[57, 58]
	Myopia[19, 20, 32, 59-62]
	Obesity[63]
	Prior PPV[29, 64, 65]
	Smoking[19, 32, 49, 66-72]
	Tobacco (smokeless)[73]
	Ultraviolet-B light exposure[54, 74]
Posterior subcapsular	Diabetes[19, 20, 31, 36, 39]
	Hypertension[19, 57, 75, 76]
	Corticosteroids (inhaled orally)[77]
	Ionizing radiation (low and high dose)[48, 78, 79]
	Myopia[19, 32, 59, 60, 62, 75]

TABLE 1 FACTORS ASSOCIATED WITH INCREASED RISK OF CATARACT DEVELOPMENT* (CONTINUED)

Cataract Type	Associated Risk Factors
Posterior subcapsular (continued)	Obesity[33, 63]
	Ocular trauma[52]
	Prior PPV[29]
	Retinitis pigmentosa[80-82]
	Smoking[71, 72]
	Systemic corticosteroid use[83]
	Topical corticosteroid use[84]
	Trauma[52]
Mixed	Diabetes[38, 39]
	Hypertension[19]
	Inactivity[85, 86]
	Inhaled corticosteroid use[87-90]
	Intravitreal corticosteroids[91, 92]
	Ionizing radiation (low and high dose)[78, 79, 93-96]
	Lower education[20, 31, 97, 98]
	Ocular inflammatory disease[99]
	Prior PPV[29]
	Smoking[72, 100, 101]
	Tobacco use (smoking and smokeless)[73]
	Trauma[102]
	Ultraviolet-B light exposure[21]

*All associations determined by observational study.

D = diopter; PPV = pars plana vitrectomy.

NATURAL HISTORY

Cataract typically progresses over time, although the type, severity, and rate of progression vary considerably among patients. With age, the lens increases in thickness and weight. Once visual acuity and function decline, the disease progresses with no chance of reversal. Three large studies demonstrate that PSCs progress more quickly than nuclear and cortical cataracts.[23, 103-105]

VISUAL FUNCTION AND QUALITY OF LIFE

The multiple components of visual function include near, intermediate, and distance visual acuity; peripheral vision; visual search; binocular vision; depth perception; contrast sensitivity; color perception; dark adaptation; and visual processing speed.[106] Visual function can also be measured in terms of patient-reported disability caused by visual impairment.[107-111] Many activities of daily living require adequate function of more than one of these visual components.

The treatment outcomes that are the most crucial and relevant to the patient are improved visual function and quality of life. Well-designed studies consistently show that cataract surgery has a substantial positive impact on vision-dependent functioning. Up to 90% of patients undergoing first-eye cataract surgery note improvement in functional status and satisfaction with vision.[112-116] Several studies report an association between improved visual function and an improved health-related quality of life.[109, 117-120] Visual function plays an important role in physical performance and well-being,[121-123] particularly with regard to mobility.[117, 124] Loss of vision in the elderly is associated with a decline in physical and mental function as well as a loss of independence in the activities of daily living.[125] Examples include daytime and nighttime driving as well as community and home activities. A 10-year evaluation of patients in the Blue Mountains Eye Study found that those who underwent cataract surgery experienced a significant improvement in mental health domain scores on the SF-36 questionnaire.[126] Cataract surgery may also help alleviate insomnia.[127, 128] The very elderly (80+ to 85+ years, depending on the study) also benefit from cataract surgery, with benefits outweighing the

ocular and systemic risks. They are just as likely to have improved visual acuity compared with younger patients, comorbidities excluded.[129-131] However, they are at slightly higher risk of developing endophthalmitis.[132]

Visual impairment, such as poor depth perception and low contrast sensitivity, is an important risk factor for falls[133, 134] and hip fractures.[135, 136] In a randomized controlled trial, first-eye cataract surgery reduced the rate of falls and fracture by 34% over a 12-month period.[117, 137] Visual loss from cataract and the increased risk of falls are both contributory factors for nursing home placement.[138] Additional studies show a reduction in mortality after cataract surgery,[139-142] and evidence exists that waiting more than 4 months to perform cataract surgery after it is clearly indicated can result in vision-related complications such as falls and accidents.[143, 144] Similar improvement following second-eye surgery has also been confirmed.[124, 145] Second-eye cataract surgery also increases the sense of independence, reduces social isolation, and improves mood and the ability to interact socially.[146]

A decrease in visual acuity and contrast sensitivity is associated with trouble driving.[106, 147-150] Drivers with visually significant cataract are 2.5 times more likely to have an at-fault motor vehicle crash over a 5-year period compared with drivers without cataract.[151] In a cohort of 277 patients with cataract, those who underwent surgery had half the rate of crash involvement compared with those who did not have surgery in a 4- to 6-year follow-up period.[152, 153] Patients who undergo cataract surgery are less likely to be in serious car crashes as the driver.[154] One large study that assessed patients' visual function preoperatively and postoperatively found the largest improvements in "driving during the day," "self-care activities," and "driving during the night."[155] Additionally, cataract surgery is shown to increase cognitive abilities in the very elderly. The majority of very elderly patients live at least 1 year following surgery, and many live much longer.[156]

In summary, numerous studies show that physical function, mental health, emotional well-being, safety, and overall quality of life can be enhanced when visual function is restored by cataract extraction.[157, 158]

Improved visual function from cataract surgery can be characterized by the following:

◆ Improved distance-corrected visual acuity[113-116]
◆ Increased ability to read or do near work[156, 159]
◆ Reduced glare[160]
◆ Improved ability to function in dim light[160]
◆ Improved depth perception and binocular vision by elimination of anisometropia and achievement of good functional acuity in both eyes[106, 135]
◆ Improved color vision[161]
◆ Improved peripheral vision[146]

Improved physical function as a beneficial outcome of cataract surgery can be characterized by the following:

◆ Increased ability to perform activities of daily living[116, 155, 159]
◆ Increased ability to continue or resume an occupation[157, 158]
◆ Increased mobility (walking, driving)[106, 147-153, 155, 159]
◆ Decreased falls[117, 133-137, 143, 144]
◆ Improved sleep[127, 128]

Improved mental health and emotional well-being as another beneficial outcome of cataract surgery includes the following:

◆ Improved self-esteem and independence[146]
◆ Improved injury avoidance[145]
◆ Improved cognition[125, 156]
◆ Better social engagement and mood[118, 146, 159]

CARE PROCESS

PATIENT OUTCOME CRITERIA

Outcome criteria can vary for each patient, depending on the patient's needs, lifestyle, and medical condition. In general, outcome criteria include the following:

◆ Reduction of visual symptoms
◆ Improvement in visual function
◆ Achievement of desired refractive outcome, including desired working distance(s)
◆ Improvement in physical function, mental health, and quality of life

DIAGNOSIS

The purpose of the comprehensive evaluation of a patient whose chief complaint might be related to cataract development is to identify the presence of a cataract, confirm that a cataract is a significant factor contributing to the visual impairment and symptoms described by the patient, and identify other ocular or systemic conditions that might be contributing to visual impairment.

Evaluation of Visual Impairment

The impact of cataract on visual function can be subjectively assessed by self-reported functional status or difficulty with vision.

Patients may adapt to their visual impairment over time, however, and may fail to notice functional decline that accompanies the insidious progression of typical cataract. Visual function may be assessed using tests that measure contrast sensitivity, glare disability, or visual acuity at near and distance. It is also possible to objectively measure the higher-order aberrations from cataract that may compromise visual acuity and quality.[162, 163]

There is no single test or measure that adequately describes the effect of a cataract on a patient's visual status or functional ability.[164] Similarly, no single test can properly define a threshold for performing cataract surgery. The Snellen visual acuity chart is an excellent tool for testing distance visual acuity in healthy eyes, and it is widely used clinically. Poor preoperative visual acuity correlates with greater postoperative functional improvement in many patients with cataract.[164, 165] Testing only at distance with high-contrast letters that are viewed in low-ambient lighting conditions underestimates the functional problems that are experienced by patients in common, real-life situations. Other important indicators of vision impairment may include daytime or nighttime glare, halos and starbursts at night (especially while driving), reduced reading speed,[120, 166] and impaired optical quality causing monocular diplopia or ghosting.[107] Cataract development makes it difficult for patients to perform basic activities of daily living such as eating and dressing, shopping, personal finances, medication management, and driving.[167] Because preoperative distance visual acuity alone may be an unreliable predictor of postoperative functional improvement, the decision to recommend cataract surgery should not be made solely on the basis of Snellen visual acuity.[113, 168]

Studies have indicated that measures of functional visual impairment provide valid and reliable information that is not reflected in the measurement of visual acuity alone.[108, 169-171]

Several patient-reported outcome measures (PROMs) have been developed.[172] Two main categories of validated questionnaires for measuring function exist; those that measure general health status (e.g., Short Form-36,[173] Quality of Well-Being Scale[170]) and vision-specific measures. Questionnaires that measure general health status provide findings that are less strongly correlated with improvement following cataract surgery than vision-specific measures.[170, 174] Examples of vision-specific instruments developed or used for cataract evaluation include the Visual Activities Questionnaire,[175] the Activities of Daily Vision Scale (ADVS),[169] the Visual Function-14 (VF-14)[107] and modified versions (e.g., VF-8R),[176] the National Eye Institute-Visual Function Questionnaire (NEI-VFQ),[177, 178] and the Catquest-9SF.[110, 179]

These questionnaires have been used as research tools to provide a standardized approach to assess visual function, and they can be compared across various time periods and populations. When compared with visual acuity measurement, the ability of questionnaires to better correlate with potential visual improvement, when used preoperatively, or to gauge improvement after surgery, is controversial.[180, 181]

Ophthalmic Evaluation

A comprehensive ophthalmic evaluation, or history and physical examination, includes those components of the comprehensive adult medical eye evaluation[182] specifically relevant to the diagnosis and treatment of a cataract as listed below.

- ◆ Patient history, including an assessment of functional status, pertinent medical conditions, medications currently used, and other risk factors that can affect the surgical plan or outcome of surgery (e.g., immunosuppressive conditions, use of systemic alpha-1 antagonists, diabetes)
- ◆ Visual acuity with correction (the power of the present correction recorded) at distance and, when appropriate, at near
- ◆ Refraction and measurement of corrected distance visual acuity (CDVA) in both eyes
- ◆ Glare testing when indicated
- ◆ Assessment of pupil size and function
- ◆ Visual field assessment
- ◆ Examination of ocular alignment and motility
- ◆ External examination (eyelids, lashes, lacrimal apparatus, orbit)
- ◆ Measurement of IOP
- ◆ Slit-lamp biomicroscopy of the cornea, anterior chamber, iris, lens, vitreous, macula, peripheral retina, and optic nerve through a dilated pupil
- ◆ Indirect ophthalmoscopy

Supplemental Ophthalmic Testing

Supplemental preoperative ophthalmic tests are not specific for a cataract but may help to identify both the cause and level of severity of an individual's visual symptoms as well as the extent to which comorbidities may be contributing to these symptoms. For most patients, an ophthalmologist can determine whether a cataract is responsible for an individual patient's visual loss by comparing slit-lamp biomicroscopy findings with the patient's specific symptoms.

Occasionally, a patient presents with visual symptoms that are disproportionate to the degree of cataract formation. Visual acuity testing alone does not quantify certain visual symptoms, such as disability due to glare and reduced contrast sensitivity.[183-187]

Optical Testing

Glare testing determines the degree of visual impairment in the presence of light scatter. Cataracts may produce a severe visual disability in brightly lit scenarios, such as sunny daytime lighting or oncoming automobile headlamps at night. The visual acuity of some patients with cataract may be normal or near normal when tested in a darkened examination room, but when retested in the presence a source of glare, it (or contrast sensitivity) may drop significantly.[188] However, significant reduction in visual acuity with glare testing is by no means specific for cataract since the etiology may be secondary to other conditions, such as ocular surface disease. Accordingly, correlation with slit-lamp biomicroscopy findings is required to establish cataract as the etiology. Stray light (or light scatter) can be measured and may be used for the evaluation of glare and indication for cataract surgery.[189]

Contrast sensitivity testing measures the patient's ability to detect subtle variations in shading by using figures that vary in contrast, luminance, and spatial frequency and is a more comprehensive and time-consuming measure of visual function than Snellen testing. For the patient who complains of visual loss and has lens changes, contrast sensitivity testing may demonstrate a loss of visual function that is not appreciated by Snellen testing alone.[184, 185, 190, 191] Contrast sensitivity (along with Snellen visual acuity) may decline for a number of reasons, and therefore, this test is not a specific indicator of cataract. In spite of

substantial progress over the past years, there remains no standard or universally preferred method for contrast sensitivity testing.

Ocular wavefront imaging has demonstrated that even relatively mild cataracts may cause visual aberrations. For example, the naturally occurring negative spherical aberration of the crystalline lens, which offsets the stable and naturally occurring positive spherical aberration of the cornea, typically changes to positive spherical aberration later in life as cataract develops, leading to a decrease in contrast sensitivity.[192, 193] This may explain the symptoms reported by some older individuals who have a mild lens opacity and reasonably good CDVA.

Corneal Testing

Measuring corneal aberrometry might be useful during IOL selection and help identify appropriate candidates for advanced technology IOLs.[194, 195]

Assessment of tear function is also important. Reduced tear meniscus and tear breakup time (less than 10 seconds), debris in the tear film, a low basal tear secretion score on Schirmer testing, filaments, or punctate erosions are all indicators of tear dysfunction that may compromise preoperative keratometry and the postoperative result.[196]

Specular microscopy and corneal pachymetry can be used to evaluate patients with known preoperative corneal endothelial disease to determine whether the cornea is likely to remain clear following cataract surgery. These tests are usually unnecessary in healthy eyes. However, they may be useful in eyes where corneal endothelial function is suspected to be abnormal as a result of endothelial dystrophies, previous ocular surgery, or trauma. Several studies suggest that specular microscopy has relatively low accuracy in predicting corneal clarity following cataract surgery.[197, 198]

Although not routinely necessary, assessment of the corneal contour using topography or tomography may be useful to determine whether irregularities in corneal power and shape are contributing to visual impairment. Additionally, a corneal contour evaluation is helpful in the assessment and management of regular and irregular astigmatism, especially when considering advanced technology IOLs or corneal relaxing incisions in conjunction with cataract surgery. Additionally, tomography devices can evaluate posterior corneal astigmatism to aid in toric IOL selection or astigmatism management.[199-202] Manual keratometry is a simple tool for assessing the degree of surface irregularity, which can contribute to visual disability.

Gonioscopy, anterior segment optical coherence tomography (OCT) and ultrasound biomicroscopy can be useful for evaluating complex anterior pathology such as narrow angle configuration, posterior polar cataract, or subluxated lenses.[203]

Macula Testing

Optical coherence tomography is very useful before cataract surgery to evaluate foveal architecture and identify the presence of concomitant retinal disease,[204-206] even when the foveal center and immediately surrounding areas appear normal on direct examination. Preoperative evaluation with macular OCT may be considered when visual acuity or impairment are disproportionate to the degree of cataract to identify retinal disease that may either be treatable or may impact postoperative visual prognosis. Macular OCT can detect an epiretinal membrane, which will increase the risk of cystoid macular edema (CME) and unexplained vision loss postoperatively. Fluorescein angiography is sometimes performed when abnormalities of the circulation of the posterior pole are suspected.

When a patient corrected for near can read small print through a pinhole on a brightly illuminated card, this indicates that the macula has some function.[207-209]

B-scan ultrasonography is appropriate when a dense cataract or other media opacity precludes adequate visualization of the posterior segment or to detect the presence of an intraocular mass, retinal detachment (RD), or posterior staphyloma.

Electrophysiologic testing (e.g., electroretinography and visual evoked potential) measures the electrical response to presented visual stimuli and indicates potential retinal function, which may be helpful in nonverbal patients.

Optic Nerve and Central Nervous System Testing

Rarely, a formal visual field test will reveal that optic nerve or central nervous system disease is responsible for central visual loss rather than, or in addition to, cataract. If concomitant glaucoma is present, optic disc photography, retinal nerve fiber layer imaging, or retinal ganglion cell analysis may be indicated. If an optic neuropathy or post-chiasmal disorder is suspected, preoperative assessment by a neuro-ophthalmologist should be considered.

MANAGEMENT

Prevention

Preventive measures that impart even a modest decrease in the risk of cataract could have a large public health impact, given that 24.4 million people over the age of 40 years in the United States are affected by cataract.[5]

The role of diet and antioxidant supplements has been studied with mixed conclusions. A 2012 Cochrane Systematic Review of nine randomized controlled trials found no evidence to support high doses of vitamin E, vitamin C, or beta-carotene in preventing development or progression of cataract.[210] *(I+, Good, Strong)* A more recent systematic review about the role of nutrient supplementation on lens pathology found that vitamin C, beta-carotene, and lutein and zeaxanthin had a protective effect against cataract, but this analysis included observational data.[211] There is currently no level 1 evidence to suggest that high-dose antioxidant supplementation slows cataract progression. There is moderate evidence that a multivitamin/mineral supplement may decrease the risk of cataract.[20, 212-214]

Several observational studies also demonstrate the potential benefit of a healthy diet in preventing cataract.[215-220] There is currently insufficient evidence to support a specific diet, but a well-balanced diet rich with fruits and vegetables is a reasonable recommendation based on observational studies.[216] Appendix 3 summarizes studies of nutrition and cataract.

Long-term increased physical activity and exercise may decrease the risk of cataract.[86, 221, 222] Additionally, long periods of inactivity and prolonged sitting may be associated with cataract progression.[85, 86]

The effect of medications on the formation of cataract is difficult to study since the effect of the medication is hard to distinguish from the effect of the disease being treated. Long-term users of inhaled or oral corticosteroids are at higher risk of cataract formation.[51, 77, 83, 87, 88, 223] The use of intranasal corticosteroids, however, is not associated with a significant risk of incident cataract based on two recent systematic reviews.[84, 224] The association between statin use and cataract has been studied extensively with conflicting results.[225-231] Phenothiazines have been associated with anterior subcapsular opacities.[232, 233] Multiple studies show no benefit of aspirin on cataract development or the need for cataract surgery.[234-238] There is a long list of drugs that may be associated with cataract in prevalence studies, but longitudinal studies are needed to confirm a causative relationship.[51, 239, 240] Patients on medications who are at high risk for cataract formation should be counseled and monitored.

The presence of diabetes mellitus,[19, 20, 37-39] hypertension,[39, 57, 75, 241, 242] obesity,[33, 34, 39, 243] and metabolic syndrome (diabetes, hypertension, obesity, and dyslipidemia)[46, 242, 244, 245] is associated with an increased risk of cataract or cataract surgery in numerous observational studies. Prevention and treatment of these conditions may reduce the risk of cataract.

Smoking is a risk factor for various types of cataracts, with a dose-response effect seen for nuclear sclerosis.[19, 20, 49, 66-68, 71, 72, 100, 246, 247] Cessation of smoking reduces the risk of cataract development or progression and cataract surgery, and patients should be counseled to quit smoking.[67, 68, 100, 101, 248, 249, 32, 101, 250]

A cumulative lifetime exposure to ultraviolet-B radiation has been associated with lens opacities.[21, 53, 54, 74, 251, 252] Therefore, brimmed hats and ultraviolet-B blocking sunglasses are reasonable precautions to recommend to patients.[32, 48]

Ionizing radiation is a proven cause of cataracts.[48] A recent study of U.S. radiologic technologists suggested an elevated risk of cataract even at relatively low exposures.[96] Therefore, the use of radiation protective shields and lead glasses is advisable.

Several studies demonstrate an increased risk of cataract with blunt and penetrating trauma.[52, 102, 253, 254] Therefore, safety glasses are recommended for high-risk recreational or work activities.

Nonsurgical Management

The management of visually significant cataract is primarily surgical. However, there are nonsurgical means for managing the symptoms of cataract before surgery is necessary.

Changes to glasses and contact lens prescriptions can often be made to account for refractive shifts in the early stages of cataract development. Low-vision devices can maximize remaining vision pending cataract surgery or allow surgery to be deferred in patients at high risk of complications.

Currently, no pharmacological treatments are known to eliminate existing cataract or retard its progression. Ophthalmologists should advise patients that, at this time, there is insufficient evidence to support the use of pharmacological treatments for cataract, based on a 2017 Cochrane Systematic Review of N-acetylcarnosine drops.[255] *(I+, Good, Strong)*

Patients who are long-term users of topical ophthalmic, periocular, oral, and inhaled corticosteroids should be informed of the increased risk of cataract development[51, 83, 87, 88, 90, 256-258] and may wish to discuss alternative treatments with their primary care physician. In limited circumstances, and often as a temporizing measure, the pupil can be dilated to provide better vision around a small central cataract. However, this strategy may worsen glare disability.

Surgical Management

The predominant method of cataract surgery in much of the world is sutureless, small-incision phacoemulsification with foldable IOL implantation performed on an outpatient basis.[259] Sutures or sealants are used for incision closure if needed. In randomized clinical trials, phacoemulsification produces better uncorrected distance visual acuity (UDVA) and a lower rate of surgical complications, such as iris prolapse and posterior capsule rupture, than manual extracapsular cataract extraction (ECCE) with incision closure by sutures or manual small-incision cataract extraction (MSICS).[260, 261] Phacoemulsification limits the astigmatic changes that occur with larger incisions and enables both astigmatism management and the implantation of specialty IOLs.[262] In economically disadvantaged countries, MSICS remains popular because of its cost-effectiveness, and sutureless ECCE with IOL implantation performed very well compared with phacoemulsification in one randomized clinical trial.[263]

Indications for Surgery

The primary indication for cataract surgery is a decline in visual function such that it no longer meets a patient's visual needs and for which surgery provides a reasonable likelihood of improvement. Other indications for cataract removal include the following:

- There is clinically significant anisometropia in the presence of a cataract.
- A lens opacity interferes with optimal diagnosis or management of posterior segment pathology.
- A lens causes inflammation and related secondary glaucoma (phacolytic, lens particle, phacoantigenic).
- The lens induces primary angle closure or other forms of lens-related glaucoma.

Contraindications to Surgery

Surgery for a cataract should not be performed under the following circumstances:

◆ Tolerable refractive correction provides vision that meets the patient's needs and desires.
◆ Surgery is not expected to improve visual function and no other indication for lens removal exists.
◆ The patient cannot safely undergo surgery because of coexisting medical or ocular conditions.
◆ Appropriate postoperative care cannot be arranged.
◆ The patient or patient's surrogate decision maker is unable to give informed consent for nonemergent surgery.

Preoperative Evaluation and Counseling

The ophthalmologist who will perform cataract surgery should do the following:[264, 265]

◆ Examine the patient preoperatively (see Ophthalmic Evaluation section).
◆ Ensure that the documented evaluation accurately reflects the symptoms, findings, and indications for treatment.
◆ Obtain informed consent from the patient or the patient's surrogate decision maker after discussing the risks, benefits, and expected outcomes of surgery, including the patient's expected surgical experience and the anticipated refractive outcome.[266]
◆ Review the results of the presurgical evaluation with the patient or the patient's surrogate decision maker.
◆ Counsel the patient about postoperative refractive options, such as bilateral emmetropia, bilateral myopia, or monovision, that will work best given the ophthalmic history and patient's desires.
◆ Counsel the patient about elective refractive options, such as astigmatism management, intraoperative refractive guidance, specialty IOLs (toric, extended depth of focus, multifocal, accommodating, and postoperative power adjustable), and postoperative refractive enhancement.
◆ Consider the effect of ocular comorbidities in the cataract care process.
◆ Formulate a plan, including preoperative medical management, selection of appropriate anesthesia, surgical approach, concurrent procedures, and IOL design and power.
◆ Assess relevant aspects of the patient's mental and physical status, such as the ability to cooperate and position for surgery.
◆ Formulate a postoperative care plan and inform the patient or the patient's surrogate decision maker of these arrangements (setting of care, care provider).
◆ Determine the effect of any concurrent upper-eyelid blepharoptosis. Blepharoptosis can induce corneal astigmatism or make astigmatism more difficult to measure. Additionally, cataract surgery can worsen blepharoptosis.[267]
◆ Answer the patient's questions about the surgery and care, including associated costs.
◆ Assess barriers to communication, including language or hearing impairment.
◆ Ensure that the patient and the patient's caregiver, if applicable, are committed and able to attend the postoperative visits and address transportation, medication administration, and other potential challenges.

Ideally, the operating ophthalmologist should perform the preoperative assessment because this allows the surgeon to formulate a plan and establish a relationship with the patient before surgery. Although the ophthalmologist is responsible for the examination and review of the data, certain aspects of data collection may be conducted by other trained team members under the ophthalmologist's supervision and with his or her review.[264, 265]

Patients undergoing cataract surgery frequently have a preoperative medical evaluation, including a history and physical examination that takes into consideration the risk factors for undergoing the planned anesthesia. However, three randomized clinical trials have failed to show that this evaluation reduces systemic or ocular complications[268] and no trials have shown it to be efficacious. For patients with certain severe systemic diseases (e.g., chronic obstructive pulmonary disease, poorly controlled arterial blood pressure, recent myocardial infarction, unstable angina, poorly controlled congestive heart failure, or poorly

controlled diabetes), a preoperative medical evaluation by the patient's primary care physician or a dedicated preoperative service may be considered.[269]

Routine preoperative laboratory testing in association with the history and physical examination is not indicated. A very large, prospective, randomized clinical trial demonstrated that routine medical testing did not reduce perioperative morbidity and mortality.[270] Despite this finding, routine medical testing is still performed on many Medicare recipients.[271] Directed testing may be recommended as appropriate for a particular surgical candidate with medical problems.[268, 270, 272]

Biometry and Intraocular Lens Power Calculation

Optical biometry refers to highly accurate and non-invasive methods for measuring anatomical characteristics of the eye by optical methods. Optical biometry devices for measuring axial length initially used partial coherence interferometry as a replacement for ultrasound. If a signal-to-noise ratio is adequately high, interferometry is significantly more accurate and consistent than contact (applanation) A-scan biometry.[273-275] In applanation A-scan, an ultrasound probe compresses the cornea, causing both a variable and artificial shortening of axial length. The accuracy and overall consistency of applanation ultrasound techniques are highly dependent on the skill and experience of the operator.[274, 276, 277] When the immersion A-scan ultrasound technique is used, the probe does not come in direct contact with the cornea, making the measurements more consistent and accurate.

Optical biometry was once considered comparable to immersion A-scan biometry, but it has since been shown to produce better refractive outcomes. The patient's postoperative spherical equivalent is also more likely to be closer to the target refraction.[278-280] Optical biometry has also been shown to give user-independent results.[281] Other advantages over A-scan ultrasonography include ease and speed of automated operation and the ability to measure to the fovea when proper fixation is achieved. Optical biometry can also obtain additional measurements required for newer and potentially more accurate IOL formulas. A newer form of optical biometry, swept-source OCT, allows for measurement through an even greater percentage of cataracts and other media opacities than partial coherence interferometry.[282-286]

A shortcoming of optical biometry is that it currently assigns a global refractive index to the entire eye rather than adjusting to the specific optical elements (e.g., cornea, aqueous humor, lens, and vitreous humor) through which light passes. In a highly myopic eye measured using an optical biometer, the axial length of the vitreous gel relative to the other structures results in an overestimation of the true axial length, causing an underestimation of IOL power using standard formulas. To compensate for this effect, approaches such as the Wang-Koch adjustment can be applied to the axial length for eyes longer than 25 mm.[287] However, the Wang-Koch adjustment is not to be used with newer-generation formulas such as the Barrett Universal II or Hill-RBF formulas, or with any of the specialized formulas used to calculate IOL power in eyes with a history of keratorefractive surgery.

Because optical biometry measures the "refractive" axial length rather than the anatomical axial length, this method is more accurate than standard forms of ultrasound A-scan biometry when the fovea is located on the sloping wall of a posterior staphyloma.[288] Additionally, it is easier to use optical biometry than ultrasound when a patient has silicone oil in the posterior segment.[289, 290] Despite recent advances in optical biometry that allow the measurement of axial length through increasingly dense cataracts,[282-286, 291] A-scan biometry may be necessary to measure axial length in certain dense cataracts or when a patient is unable to fixate properly.[292, 293] The measurement and comparison of axial length for both eyes is advisable, even if surgery is not planned for the fellow eye.

Formulas for calculating IOL power rely on keratometry to determine the net refractive contribution of the cornea. These measurements can be obtained by manual or automated keratometers, biometers, topographers, Scheimpflug tomographers, and anterior segment OCT devices (see Table 2). Following keratorefractive surgery, the determination of true

central corneal power is particularly challenging (see Cataract Surgery Following
Refractive Surgery in the Combined Surgery and Special Circumstances section).

TABLE 2   INTRAOCULAR LENS POWER CALCULATION
FORMULAS

Formula	Variables in Addition to Keratometry and Axial Length	Notes
Barrett Universal II	• Anterior chamber depth • Lens thickness • White-to-white	• Uses a theoretical ray-tracing formula with data-driven enhancement • Model eye correlates axial length and keratometry to anterior chamber depth • Includes location of the principal plane of refraction of the IOL
Haigis	• Anterior chamber depth	• Uses double regression analysis to optimize three variables
Hill-RBF	• Anterior chamber depth • Lens thickness • White-to-white	• Uses artificial intelligence for pattern recognition and data interpolation
Hoffer Q[294-296]	• None	• Optimizes equation constant (personalized anterior chamber depth)
Holladay 1	• None	• Optimizes surgeon factor to derive anterior chamber depth
Holladay 2	• Anterior chamber depth • Lens thickness • Age • White-to-white • Preoperative refraction	• Adds additional variables to Holladay 1 • Updated with nonlinear regression model
Kane[297, 298]	• Anterior chamber depth • Biological sex • Lens thickness • Central corneal thickness	• Based on theoretical optics incorporating regression and artificial intelligence components
Olsen[299]	• Anterior chamber depth • Lens thickness	• Uses ray tracing and thick lens calculations to derive the C constant
SRK/T[300]	• None	• Combines theoretical optics with regression analysis • T2 formula uses regression analysis to update SRK/T

IOL = intraocular lens

Although IOL manufacturers supply lens constants to be used with calculation formulas, these numbers are generally considered to be only a recommendation and may not correspond to the biometry method actually used. Optimization of lens constants for a specific IOL based on an individual surgeon's actual refractive outcomes may be helpful, as may online databases pooling information from multiple surgeons.[301]

The surgeon should consider the patient's desires and needs when selecting an appropriate postoperative refractive target. Patients with high myopia may require unique lens constants for plus and minus power IOLs that are quite different from those recommended by the manufacturer because of IOL geometry.[302, 303] For patients with extreme hyperopia who require an IOL beyond the available power range, piggybacking two posterior chamber IOLs is possible, including as a staged procedure.[304-308] When this is indicated, it

is highly preferable to place one IOL in the capsular bag and one in the sulcus to reduce the risk of interlenticular membrane formation.[309, 310]

Corneal relaxing incisions can correct small amounts of preoperative corneal astigmatism, but for larger amounts, toric IOLs should be considered.[311-313] A 2016 systematic review and meta-analysis found that toric IOLs provided lower amounts of residual astigmatism than nontoric IOLs, even when corneal relaxing incisions were used.[312] *(I+, Good, Strong)* Toric lenses available in the United States are designed for implantation within the capsular bag. Toric calculators require preoperative measurement of the corneal cylinder and a knowledge of surgically induced astigmatism. Adding the contribution of the posterior cornea has been shown to improve outcome accuracy, whether by nomogram or by measuring the posterior cornea directly.[314-317] The power of the toric component should be adjusted for the effective lens position of the IOL.

Most modern IOLs contain aspheric optical surfaces. These lenses improve mesopic and scotopic contrast sensitivity and visual quality by reducing or eliminating spherical aberration.[318-322] However, they are less tolerant of tilt and decentration and might not be the best choice in patients with zonulopathy.[323] Some surgeons choose the asphericity of an IOL to match the asphericity of the cornea to maximize visual quality under mesopic and scotopic conditions.[324, 325]

Intraocular lens power can be confirmed or refined intraoperatively in the aphakic and pseudophakic states using intraoperative aberrometry. Aberrometry can assist with toric IOL axis alignment as well.[326] Intraoperative aberrometry can be useful in eyes with a history of keratorefractive surgery such as photorefractive keratectomy (PRK) and laser-assisted in situ keratomileusis (LASIK), although it is not as useful after radial keratotomy.[327, 328] It is not clear that intraoperative aberrometry always improves outcomes.[329-332]

Anesthesia

Cataract surgery may be performed using a variety of anesthesia techniques that include local (regional) anesthesia (e.g., retrobulbar, peribulbar, sub-Tenons injection, intracameral, and topical) and occasionally general anesthesia. The planned mode of anesthesia should be discussed with the patient so that she or he knows what to expect in terms of pain, discomfort, consciousness level, visual experiences, and complications. The outcomes of cataract surgery measured in terms of visual acuity, visual function, complications, adverse medical events, and patient satisfaction have not been shown to vary significantly between the anesthesia techniques.[333-340] Intravenous (IV) sedation is commonly used to complement the local anesthesia to optimize a patient's surgical experience and cooperation.

Anesthesia techniques with needles or blunt cannulas may be associated with complications that are not encountered with topical/intracameral techniques. Complications include strabismus, globe perforation, retrobulbar hemorrhage, intravascular or subarachnoid injection, and macular infarction.[333, 337-341] Eyes with posterior staphylomas or scleral buckles are at increased risk for globe perforation by peribulbar or retrobulbar injections.[342]

A Cochrane Systematic Review of randomized clinical trials (RCTs) comparing peribulbar with retrobulbar blocks found no difference in efficacy (in terms of akinesia, anesthesia, or need for supplemental injections) or safety.[336] *(I+, Good, Strong)* Conjunctival chemosis was more likely with peribulbar blocks, whereas lid hematoma was more likely with retrobulbar blocks.

A 2015 Cochrane Systematic Review of RCTs comparing topical with sub-Tenon's anesthesia found greater intraoperative but less postoperative pain at 24 hours with topical anesthesia.[343] While statistically significant, the magnitude of differences in pain was not clinically relevant. There was insufficient evidence to draw conclusions about the incidence of surgical complications between the two techniques. *(I+, Moderate, Discretionary)*

Patients undergoing cataract surgery with topical or peribulbar anesthesia occasionally experience visual sensations such as seeing lights, colors, the movement of instruments, and the surgeon's hand or fingers. Because 3% to 18% of patients find these visual sensations disturbing, preoperative counseling about these phenomena may make their occurrence less frightening.[344, 345]

Intravenous access is recommended to treat potential adverse events when sedation/analgesic agents are administered.[346] A systematic review and meta-analysis found IV sedation was significantly associated with a decrease in pain when compared with non-intravenous methods.[347] *(I+, Good, Strong)* However, given the trend toward topical anesthesia and the reduction or elimination of IV analgesia/sedation, IV access may be unnecessary. Topical anesthetic drops may be supplemented with preservative-free intracameral lidocaine for increased pain control.[348] Monitoring during administration of anesthesia and surgery generally includes using a cardiac monitor, pulse oximeter, and measurement of blood pressure and respiration. These should be performed by personnel (other than the operating ophthalmologist) qualified to monitor and manage the patient's systemic status. One study of patients receiving peribulbar anesthesia found that being under age 60 and/or having hypertension, pulmonary disease, renal disease, or a prior or current diagnosis of cancer was associated with the need for intervention by anesthesia personnel, while an abnormal preoperative electrocardiogram or presence of diabetes was not predictive of the need for intervention.[349] Several studies reported on using registered nurses[350, 351] or respiratory therapists trained as sedation nurses to administer anesthesia.[352] Office-based cataract surgery is currently being studied, and large studies of patient outcomes are being performed at several Kaiser Permanente locations. Kaiser is a managed health care provider in the United States. There is insufficient evidence to make a definite recommendation currently.[353]

A review of cataract surgery studies involving local anesthesia found weak evidence for improved pain relief, anxiety control, and patient satisfaction with IV or intramuscular sedation or analgesia and insufficient evidence to recommend one technique over the other.[333] The evidence was also insufficient to determine if any analgesic or sedation regimen was better than any other. The Study of Medical Testing for Cataract Surgery found that patients experienced more postoperative drowsiness and nausea when IV agents were used and that nausea and vomiting increased significantly with the number of agents (opioid, sedative, hypnotic) used.[334] Also, excessive use of IV sedatives during cataract surgery was associated with an increased risk of an adverse intraoperative medical events, and this risk was even greater when both IV opiates and sedatives were used.[335, 354, 355] Evidence is mixed on the value of oral anxiolytic medication to reduce the patient's anxiety levels when given before cataract surgery.[354-359] Some studies demonstrated the noninferiority of oral sedation compared with IV sedation, though high-quality meta-analysis and systemic reviews are lacking.[357, 359] Patients undergoing sequential cataract surgery typically perceive more pain and discomfort during the second surgery. This suggests that preoperative expectations should be reviewed with patients undergoing second-eye surgery.[360] These measures may translate into improved patient comfort and cooperation intraoperatively.[361, 362]

Given the lack of evidence for a single optimal anesthesia strategy for cataract surgery, the type of anesthesia management should be determined by the surgeon according to careful consideration of the patient's needs, preference of the patient,[363] the medical judgment of the anesthesia team, and the surgeon.

Infection Prophylaxis

Preventing postoperative infection is a key aspect of cataract surgery because of the potentially severe consequences of endophthalmitis. Controlled trials of antibiotics have been difficult to perform because of the low incidence of endophthalmitis following cataract surgery in the United States.[364] A sufficiently controlled trial for FDA approval would require tens of thousands of subjects and an estimated initial research and development expense of over $350 million.[365] These and other factors have led to a paucity of level I evidence for endophthalmitis prophylaxis, leaving a number of large retrospective cohort studies to fill this gap.

A study found endophthalmitis rates as high as 0.327% in the 1970s decreasing to 0.087% in the 1990s when ECCE became predominant.[366] The infection rate subsequently increased and by 2003 reached 0.265% (1 infection in every 377 cases), whereas the incidence of infection after other anterior segment procedures was reportedly on the decline.[366-369] It has been proposed that the period of rising rates of infection corresponded to the increased adoption of clear corneal incisions in cataract surgery, where improperly constructed corneal incisions were prone to postoperative instability, leakage, and a potential influx of microbes compared with sclerocorneal incisions.[370-377] On the other hand, four large case series found no greater likelihood of infection with corneal versus other types of incisions during this period.[378-381] Nevertheless, careful watertight incision construction and closure (with sutures or sealants, if necessary) is obligatory, irrespective of surgical style, because the incidence of infection increases with wound leak.[382] The endophthalmitis rate after cataract surgery in the United States between 2013 and 2017 was estimated to be 0.04%.[364]

Other factors associated with increased rates of endophthalmitis include intraoperative posterior capsule rupture, vitreous loss, prolonged surgical time, immunodeficiency, active blepharitis, lacrimal duct obstruction, inferior incision location, incomplete removal of the lens cortex, male gender, older age, previous intraocular injections, lower surgical volume, and less experienced surgeons.[379, 382-394]

Role of antiseptic

Although rare clusters of infections may be induced by contaminated surgical products,[395-400] topical drops,[401, 402] or contaminated operating room environments,[403, 404] the patient's periocular flora is the primary source of microbes responsible for most cases of sporadic postoperative infection.[405]

Nonrandomized controlled trials and a prospective trial with the unoperated eye as the control provide evidence that instilling topical 5% povidone iodine in the conjunctival cul de sac preoperatively reduces the bacterial load and the incidence of postoperative infection.[406-408] A one-time application of lower concentrations of povidone-iodine was less effective in some studies at reducing conjunctival bacterial colony counts.[409-411] Other studies have shown that dilute concentrations of povidone-iodine between 0.05% and 1% have better bactericidal activity, through greater availability of diatomic free iodine, and reduce cornea toxicity and patient discomfort.[412-415] The presence of lidocaine gel prior to povidone-iodine instillation appears to diminish its antimicrobial efficacy.[416]

Chlorhexidine is not recommended because it is toxic to the ocular surface and can cause irreversible keratitis.[417]

Topical antibiotics

There is growing evidence that preoperative topical antibiotic administration is unnecessary and may increase the potential for resistance.[418-420] Although instilling antibiotics before surgery decreases the bacterial load of the ocular surface,[421] topical povidone-iodine alone was as effective as povidone-iodine combined with preoperative topical antibiotics in a randomized clinical study.[420]

A retrospective study of 315,246 cataract surgeries demonstrated that intracameral antibiotic injection was more effective at preventing postoperative endophthalmitis than topical antibiotic administration alone.[393] No difference in effectiveness was apparent between topical gatifloxacin, ofloxacin, or polymyxin/trimethoprim; however, topical aminoglycoside use was associated with double the rate of postoperative endophthalmitis, the same rate as the group with no antibiotic prophylaxis (5% of the study population). However, the small benefit of topical postoperative antibiotics was outweighed by the greater effectiveness of intracameral antibiotic injection.

Intracameral Injection in combination with postoperative topical drops

There is substantial evidence to support the injection of antibiotics intracamerally to reduce the risk of endophthalmitis. The intracameral route delivers a much higher concentration of drug to the surgical site, resulting in higher bactericidal activity compared with topical

administration.[422, 423] Following initial studies in Sweden,[423] a seminal large, prospective, randomized and partially masked trial was conducted by the European Society of Cataract and Refractive Surgeons (ESCRS).[424] The incidence of endophthalmitis after phacoemulsification was compared between four groups receiving the following: injection of intracameral cefuroxime 1 mg/0.1 mL, pulsed dosing of perioperative levofloxacin eye drops, both injection and pulsed drops, and neither injection nor drops. All groups were treated with topical postoperative levofloxacin for 6 days, starting one day after surgery. Based on intent-to-treat analysis of 16,211 patients, investigators found that the absence of intracameral cefuroxime injection was associated with a 4.92-fold increase (95% confidence interval [CI], 1.87–12.9) in the risk of postoperative endophthalmitis.[424] Numerous other retrospective studies and two prospective studies have since reported a reduction in endophthalmitis after cataract surgery when intracameral cefazolin, cefuroxime, or moxifloxacin were added to postoperative topical antibiotic drops .[393, 425-446] In one of these, the low baseline endophthalmitis rate of 0.07% fell further to 0.02% (one infection in 5,000 cases) when intracameral moxifloxacin was added.[443] A systematic review and meta-analysis of over 900,000 eyes documented the effectiveness of intracameral cefuroxime, moxifloxacin, and vancomycin in reducing endophthalmitis. Secondary analyses showed no difference in efficacy between intracameral plus topical antibiotics versus intracameral alone ($P > 0.3$). The safety analysis showed minimal toxicity for moxifloxacin. Dosing errors led to most cases of toxicity when cefuroxime was used. Although rare, vancomycin was associated with toxic retinal events.[447]

Moxifloxacin is currently the most common intracameral prophylactic agent in use in the United States, whereas cefuroxime is preferred in European countries.[448] There is no evidence to date to suggest the superiority of either agent.[393, 442] The standard dose of cefuroxime is 1 mg in a 0.1 mL injection.[424] However, there is no current universally agreed upon dose for moxifloxacin,[449] so it is important to ensure that an adequate concentration of drug is achieved in the eye at the conclusion of surgery for sufficient bactericidal activity.[450]

Several studies support the safety of intracameral moxifloxacin injection for endophthalmitis prophylaxis;[441, 446, 451] however, there is some evidence that higher concentrations may have a deleterious effect on the corneal endothelium.[452-454] Intracameral cefuroxime is available as a government-approved product in Europe, and moxifloxacin is commercially available in India. Because there is no FDA-approved product in the United States for endophthalmitis prophylaxis, moxifloxacin must be compounded for intracameral injection. Outsourcing facilities produce intracameral antibiotics in bulk and must meet stringent criteria under section 503B of the Federal Food, Drug, and Cosmetic Act.[455] Antibiotics may also be compounded on a patient-by-patient basis by 503A pharmacies, which do not have the same rigorous standards as 503B pharmacies. Onsite compounding of cefuroxime has been associated with dilution errors that have the potential for severe toxicity.[456-461] The routine injection of vancomycin for endophthalmitis prophylaxis is strongly discouraged based on its association with the rare condition hemorrhagic occlusive retinal vasculitis (HORV) after uncomplicated cataract surgery.[462, 463] Suspected cases of HORV can be registered on a joint American Society of Retina Specialists and American Society of Cataract and Refractive Surgery (ASCRS) survey (https://www.surveymonkey.com/r/HORV).

Intracameral injection alone

There is growing interest in drop-free chemoprophylaxis regimens, which would eliminate the need for the instillation of eyedrops following cataract surgery.[464, 465] Retrospective studies comparing antibiotic injection alone with combination injection and topicals have demonstrated a low frequency of endophthalmitis in the injection-only group and no difference in infection risk compared with the combination group.[466-468] In an observational study, the infection rate was higher in the combination treatment group than in the injection-only group, although this was not statistically significant (OR 1.63 ([CI]) 0.48–5.47).[393] Finally, two meta-analyses conclude there is a lack of a clear benefit to prescribing topical antibiotics when injecting an intracameral antibiotic.[447, 469] *(I+, Good, Strong)* It

should be stressed that even with the added benefit of intracameral antibiotic injection, a proper povidone-iodine prep and attention to surgical technique are important to prevent postoperative infection.[470]

Alternative prophylaxis strategies have been used. One is mixing antibiotics into the irrigation bottle, although this generally results in an inadequate drug concentration and duration of action.[406, 471] Another is subconjunctival antibiotic injection, which has been shown to be inferior to the intracameral route of injection[430, 433] because a much lower concentration of the drug reaches the anterior chamber.[472, 473] Transzonular and pars plana intravitreal injection have been proposed as alternative routes of antibiotic delivery;[474] however, large randomized studies establishing the safety and effectiveness of these approaches are lacking.[456, 475-477]

Toxic Syndromes

Substances introduced into the eye during cataract surgery may result in immediate or subsequent damage for reasons other than infection. Tissue injury may result from direct toxicity or exuberant inflammation and involve the anterior or posterior segment.

Toxic anterior segment syndrome

Toxic anterior segment syndrome (TASS) is a sterile postoperative inflammatory reaction that typically presents within 12 to 48 hours following surgery and can mimic infectious endophthalmitis.[478] Common clinical findings are diffuse limbus-to-limbus corneal edema, severe anterior chamber cell and flare, fibrin, and hypopyon. Sequelae may include an atonic pupil, secondary glaucoma, and corneal decompensation.[479] The inflammation associated with TASS usually responds to anti-inflammatory medications, but permanent intraocular damage can occur. If there is a suspicion of an infectious etiology, cultures of the aqueous humor and vitreous should be obtained to test for infectious etiologies, and antibiotic treatment should be initiated.[480]

The incidence of TASS is unknown and may vary because of its sporadic occurrence, often in clusters. A retrospective study of 26,408 consecutive cataract surgeries from a single institution in southern India during a 1-year period reported 60 cases of TASS, for an incidence of 0.22%. There were two identified clusters, but more than half of the cases were sporadic and unexplained. The visual outcomes were excellent, based on 6-month follow-up reported on 40% of cases.[481] In a series of 11,935 consecutive cataract surgeries performed at one U.S. center between 2010 and 2013, there were no reported cases of TASS. Subsequently, 10 cases of TASS in 3,003 cataract surgeries occurred in the following year.[482] Reservoirs of tabletop autoclaves were found to be contaminated and to contain microbial biofilms, which likely led to the cluster.

All the following have been associated with development of TASS:

◆ Biofilm residues formed from dried ophthalmic viscosurgical devices (OVDs) and ultrasound baths, particularly in cannulated instruments[483-485]

◆ Detergents and enzymatic cleaners[483, 484, 486]

◆ Drug preservatives, including benzalkonium chloride[479, 487]

◆ Incompatible additives such as xanthan gum in some commercially available topical moxifloxacin eyedrop preparations intended only for topical application[488]

◆ Residue on IOLs during the manufacturing process[489-491]

◆ Non-ophthalmic agents such as sterile water, methylene blue,[492] indocyanine green,[493] and gentamicin[479, 487]

◆ Contaminated manufactured ophthalmic agents such as a balanced salt solution, OVD,[478] Trypan blue,[492] and silicone oil[494]

Preventive strategies for TASS include thoroughly cleaning and sterilizing ophthalmic instruments,[478, 495] minimizing enzymatic detergents[478, 495] or thoroughly rinsing if used,[496] periodically cleaning tabletop autoclaves,[482] frequently cleaning ultrasound baths,[479, 487] and avoiding agents not specifically formulated for intraocular administration.[478] Replacing

reusable instruments with single-use, disposable products is another strategy to avoid residue, but there is increasing concern for environmental waste and emissions with this practice.[495, 497] Additional resources for the prevention of TASS and a registry to report suspected cases can be found on the ASCRS TASS task force website (https://tassregistry.org/).

Toxic posterior segment syndrome

Injected pharmaceuticals may cause toxic posterior segment syndrome (TPSS), which is temporary or permanent damage to the retina and adjacent structures resulting from a compounding error or incompatible additives. Macular edema, ischemia, and infarction have been associated with injection of excessive cefuroxime in a dose-dependent fashion[457, 459-461] as well as with the standard dose.[458 498] Permanent, severe vision loss in seven patients was attributed to intravitreal injection of a triamcinolone-moxifloxacin compound containing an unapproved binding agent produced by a single pharmacy.[456] These cases highlight the importance of obtaining injectable drugs from verified, reputable sources. Hemorrhagic occlusive retinal vasculitis is a type of delayed TPSS. Suspected cases of TPSS can be registered on the ASCRS website to aid with ongoing surveillance and research (https://tpssregistry.org/).

Cataract Surgery Checklist

Protocols to minimize the incidence of preventable surgical errors with respect to the surgical site (e.g., wrong eye) and surgical procedure (e.g., wrong IOL) describe the recommended steps to be taken before and on the day of surgery. The roles and responsibilities for different members of the health care team are delineated.[499-504] In 2008, the World Health Organization created a surgical safety checklist. The checklist was intended to be universally applicable, with adaptations to fit specific disciplines. It is administered at three critical junctures: before the introduction of anesthesia, before the incision, and before the patient leaves the operating room. It was adapted for eye surgeries by The Royal College of Ophthalmologists and the American Academy of Ophthalmology. The Wrong-Site Wrong-IOL Surgery Checklist (see Appendix 4) is an example of how to document that appropriate steps were taken to prevent wrong-site and wrong-surgery events. Adherence to presurgical protocols or checklists has resulted in fewer surgical errors and should be implemented.[500, 503, 505-509]

Surgical Techniques

Beyond the skill set needed to perform the steps of the operation, cataract surgery also requires the cognitive skills, judgment, and experience necessary to recognize and respond to unexpected events, problems, and complications that may arise intraoperatively. Only an ophthalmologist has the medical and microsurgical training as part of a comprehensive residency experience needed to perform cataract surgery.

In countries with adequate infrastructure to support advanced ophthalmic technology, phacoemulsification is the preferred method to remove a cataract.

The ideal technical elements of a successful cataract procedure include the following:

◆ A secure, watertight incision that minimizes surgically induced astigmatism or reduces pre-existing corneal astigmatism[510-513]
◆ Thorough removal of all nuclear, epinuclear, and cortical material[514]
◆ Negligible or no trauma to the corneal endothelium, iris, and other ocular tissues[515, 516]
◆ Preservation of the integrity of the lens capsule
◆ Capsular bag fixation of an appropriate posterior chamber IOL

Intraocular steps that are commonly used during phacoemulsification include the following:

◆ Construction of an appropriately sized incision that is tight enough to achieve a stable anterior chamber[517]

- ◆ Use of an OVD to protect the corneal endothelium, manipulate tissues, and maintain adequate working space during surgery[518, 519]
- ◆ Creation of a capsulorrhexis,[520] which can be made manually, or by a femtosecond laser or radiofrequency device. The capsulorrhexis aids in hydrodissection; prevents posterior capsule tears that originate from radial anterior capsule tears; and facilitates the implantation, fixation, and centration of the IOL within the capsular bag. A capsulorrhexis that completely overlaps the IOL edge limits the development of posterior capsular opacification (PCO) for some IOL designs and blocks the anterior migration of vitreous gel following a laser posterior capsulotomy.[521]
- ◆ Hydrodissection, which reduces zonular stress during phacoemulsification by mobilizing the nucleus and epinucleus, and facilitates thorough cortical aspiration.[522] Hydrodissection also helps to retard PCO.[523, 524]
- ◆ Nuclear disassembly and emulsification using techniques such as divide and conquer,[525] chopping or pre-chopping,[526] and femtosecond laser-assisted cataract surgery (FLACS) fragmentation to allow nuclear removal through a capsulorrhexis and small incision[527-529]
- ◆ Thorough removal of remaining epinucleus and cortex[514] (polishing the anterior and posterior aspects of the capsule when appropriate)
- ◆ Implantation of a foldable IOL within the capsular bag
- ◆ Removal of OVD to minimize postoperative IOP elevation[530]
- ◆ Establishment of a watertight incision by various means (raising the IOP, stromal hydration, sealant, or suture)[374, 386, 510, 531-533]

Incision location, size, and design may depend on several factors, including the patient's orbital anatomy, the type of IOL to be implanted, the role of the incision in astigmatism management, and surgeon preference and experience. For example, varying the incision characteristics and centering it on the steep corneal meridian may reduce pre-existing astigmatism.[534-537]

When feasible, small-incision surgery is generally preferred for several reasons.[538] Smaller incisions are more amenable to self-sealing wound construction, are inherently safer in the event of sudden patient movement or a suprachoroidal hemorrhage during surgery, and lead to fewer physical restrictions postoperatively. They are also associated with less initial postoperative inflammation and less unwanted astigmatic change.[538-549]

When required, manual ECCE or MSICS may be preferred for certain cataract surgeries, such as those with mature nuclei, weak zonular fibers, or a higher risk of corneal decompensation.[550-554] Chang reported no significant difference in outcome between phacoemulsification and MSICS in a prospective comparison between two experienced surgeons.[263]

Femtosecond lasers can be used to construct corneal incisions,[555, 556] create astigmatic relaxing incisions,[557-559] perform an anterior capsulotomy, and fragment or soften the nucleus.[527, 528]

A 2020 meta-analysis of 73 studies was published in the *Journal of Cataract & Refractive Surgery* comparing 12,769 eyes that underwent FLACS procedures with 12,274 conventional cataract procedures. It showed significantly improved uncorrected and corrected visual acuity at 1 to 3 months, along with significantly decreased cumulative dissipated energy, improved capsulorrhexis circularity, decreased central corneal thickness at 1 day and at 1 to 3 months, and decreased endothelial cell loss at both 3 to 6 weeks and at 3 months. However, anterior capsular ruptures were found to be more common with FLACS. No differences in visual acuity were found at 1 week and after 6 months, and there was no difference in posterior capsule rupture rates and endothelial cell loss after 6 months. See the Outcomes section for a full discussion.

Intraocular Lens Materials, Design, and Implantation

Intraocular lens implantation is the method of choice for correcting aphakia, unless there are specific contraindications.[560] Posterior chamber IOL implantation inside the capsular bag is the optimal method for most cases.[561]

Cataract surgeons can choose from a wide variety of posterior chamber IOL styles and materials to find an appropriate lens to match their patients' needs. Intraocular lens optic size, shape, haptic configuration, optic edge design,[562-565] optic and haptic materials,[566-568] and chromophore content are engineered with a variety of characteristics.[569, 570]

Foldable IOLs are commonly used because of their ability to fit through small incisions, and they have largely replaced rigid polymethyl methacrylate (PMMA) posterior chamber IOLs. Foldable IOLs can be made from silicone, hydrophilic acrylic, and hydrophobic acrylic. All foldable IOL materials are associated with minimal giant-cell foreign-body reaction.[571-573] Surgeons should be familiar with the unique positive and negative features of each IOL type with regard to material, design, and insertion system.

Silicone IOLs:

◆ Incidence of PCO is low, especially with capsulorrhexis overlap.[574]

◆ Use in patients with silicone oil or expansile gas in the posterior segment may compromise surgical visibility and should be avoided.[575, 576]

◆ Use in eyes at high risk of future retinal surgery, such as those with severe proliferative diabetic retinopathy, should be avoided.

Hydrophobic acrylic IOLs:

◆ Sharp-edged IOLs decrease the incidence of PCO, especially in the presence of capsulorrhexis overlap.[574] This finding holds true for IOLs made from other materials as well.[577]

◆ Glistenings, which are fluid-filled vacuoles, may develop in some lenses but rarely affect vision or require explantation.[578-582]

◆ Blue filtering IOLs have not been clearly shown to protect the macula, based on a 2018 Cochrane Systematic Review *(I+, Good, Discretionary)*, nor do they seem to impair color discrimination.[583]

Hydrophilic acrylic IOLs:

◆ Use in patients undergoing keratoplasty or vitrectomy may result in IOL calcification upon exposure to intraocular air or gas and thus should be avoided.[584]

◆ The incidence of PCO is higher with hydrophilic acrylic IOLs than with silicone or hydrophobic acrylic IOLs.

Foldable IOLs can be inserted with forceps or injection devices; in many cases IOLs come preloaded in insertion devices.[585, 586] Insertion devices facilitate consistently reproducible insertion through small incisions while preventing any contact of the lens with debris or microorganisms residing on the patient's ocular surface.[587] Preloaded insertion reduces the risk of improper IOL loading at the time of surgery, which may result in IOL optic scratches, haptic kinking, or other damage, or an IOL flipping upside down.

Intraocular Lens Optical Considerations

Spherical IOLs, in which marginal light rays focus proximally relative to paraxial light rays, have positive spherical aberration. Positive spherical aberration results in a myopic shift and increased depth of focus when the pupil dilates.

Some aspheric IOLs are designed to compensate for the spherical aberration of the cornea. Multiple clinical studies demonstrate a pupil-dependent reduction in ocular spherical aberration with aspheric IOLs, and some studies also reveal varying degrees of superior contrast sensitivity with these IOLs relative to spherical IOLs.[325, 588-600] However, the potential advantages of aspheric IOLs remain controversial, particularly with respect to functional benefit[601-603] and depth of focus.[162, 604] The potential advantages and

disadvantages can be affected by pupil size,[605] IOL tilt[606] and decentration,[607] and whether the spherical aberration of the IOL and the patient's cornea are custom matched.[324, 608-613]

Between 15% and 29% of cataract patients have more than 1.5 D of keratometric astigmatism.[614, 615] Toric IOLs, which correct for astigmatism, have been shown to decrease eyeglass dependence compared with nontoric monofocal IOLs.[616-619] In addition, they may offer better predictability and stability of correction compared with incisional astigmatic keratotomy, based on a 2019 Cochrane Systematic Review.[620-624] *(I+, Good, Strong)*

For a toric IOL to be effective, the axis and magnitude of corneal or keratometric astigmatism must be accurately measured, and the IOL must be accurately and permanently aligned.[625] The lenticular contribution to refractive astigmatism is eliminated with cataract surgery; thus, preoperative manifest refractive astigmatism is irrelevant in astigmatism planning. Toric IOL axis misalignment may reduce the desired refractive effect or may even worsen the overall astigmatism.[626] Because toric IOLs do not correct irregular astigmatism, they should be used cautiously in patients who might require a rigid contact lens postoperatively.[627] Modified keratometers and aberrometers, collectively known as intraoperative refractive guidance devices, are available to help with IOL power refinement and toric IOL alignment intraoperatively.[328, 628-631] An effort should be made to determine the true corneal refractive power, which incorporates both the anterior and posterior corneal power, either by direct assessment or by algorithmic adjustment.[620, 632-638]

Use of presbyopia-correcting IOLs or monovision may improve quality of life by reducing eyeglass or contact lens dependence after cataract surgery.[639] For each of these options, patient selection is critical. Certain patient-related factors may be associated with suboptimal postoperative performance and reduced patient satisfaction. Surgeons must understand an individual patient's lifestyle and expectations so that the most appropriate IOL can be selected. Patients should be informed of the potential compromise in quality of vision associated with the various choices.[640-644]

Monovision involves correction of one eye for distance vision and the fellow eye for intermediate or near vision. The success of monovision depends on interocular blur suppression where the blurred image from one eye does not interfere with the image from the eye in focus.[645] In one study, when the dominant eye was corrected for distance visual acuity, the overall monovision acceptance rate following cataract and IOL surgery was 90% in patients with cataract who desired independence of correction with eyeglasses.[646] In another study that analyzed modified monovision (-0.75 D anisometropia) versus conventional monovision (-1.75 D or more anisometropia), the authors found that binocular vision in relation to contrast sensitivity and stereopsis was better preserved with modified monovision but near vision was compromised.[647] In a small nonrandomized study comparing patients who had bilateral multifocal IOLs versus bilateral monofocal IOLs implanted to achieve monovision, there was no statistical difference in bilateral uncorrected distance and near vision or in the satisfaction scores.[648] Patients with a history of successful adaptation to monovision with eyeglasses or contacts lenses are particularly well suited for this modality.[649, 650] Such patients may benefit from distance-corrected eyeglasses for driving at night. In general, patients with latent strabismus, macular disease, or optic nerve disease are poor candidates for monovision, unless they have previously done well with optical correction.[651-655]

Presbyopia-correcting IOLs can be classified as multifocal or accommodative. Multifocal lenses have near and distance elements in the optic of the lens, and accommodative lenses change position, shape, or refractive index. When the focal points of the defocus curve of a multifocal IOL are relatively close together, producing a minimal drop in visual acuity between peaks, the lenses are said to have extended depth of focus (EDOF).[656] There is usually a measurable drop in unaided visual acuity between the peaks of the defocus curve foci of a standard bifocal multifocal IOL.

Extended depth of focus lenses can be implanted for bilateral distance focus or in a monovision arrangement. They are often favored over full-add bifocal or trifocal IOLs for eyes with subtle macular pathology or a history of keratorefractive surgery.[657-660] Extended

depth of focus IOLs come in diffractive and nondiffractive designs, and each has advantages and disadvantages with respect to glare, halos, near focus, and contrast loss.

Multifocal IOLs achieve their effect by dividing incoming light into two or more focal points and can be classified as refractive, diffractive, or a combination.[661, 662] They come in bifocal, trifocal, and quadrifocal varieties.[663] Some lenses are pupil-size dependent.[664] Optical effects of multifocal IOLs may include reduced contrast sensitivity, halos around point light sources, multiple images, and glare.[665] A 2019 systematic review and meta-analysis found that patients have better near and intermediate vision with multifocal IOLs and have greater spectacle independence but are more likely to have glare, halos, and reduced contrast sensitivity than patient with monofocal IOLs.[666] *(I+, Good, Strong)* Whether the improvement in near unaided acuity outweighs the optical side effects of multifocal IOLs varies among patients, with important factors being the motivation to achieve eyeglass independence, residual refractive error, posterior capsular wrinkles and opacities, and adaptation over time.[666, 667] Patient selection and counseling are particularly important with these IOLs. There may be a symptomatic reduction in the quality of distance vision, particularly if other ocular pathology is present, such as macular disease, advanced glaucoma, or latent strabismus. Therefore, the candidacy of patients with amblyopia or abnormalities of the cornea, optic disc, or macula for a multifocal IOL must be carefully considered.[644]

Toric multifocal IOLs correct astigmatism and concurrently provide a range of vision. When compared with spherical multifocal IOLs combined with peripheral corneal relaxing incisions, they were found to be more predictable and to have good rotational stability.[618, 668]

Bifocal IOLs with low adds for near vision are available to help minimize issues of halo and glare.[669, 670]

In an attempt to mimic human accommodation, accommodative presbyopia-correcting IOLs, with or without a toric component, are designed to change their position or shape in the eye with accommodative effort.[671] These IOLs have demonstrated varied accommodative potential without the loss of contrast sensitivity inherent in multifocal IOLs.[672-675] A modified monovision technique with the nondominant eye corrected for -0.50 D or -0.75 D is used by some surgeons to improve uncorrected near vision.

Postoperative in situ power adjustment is a recent advance in IOL power refinement.[676, 677] After refractive stability is achieved, the power of certain IOLs can be adjusted to reduce or eliminate refractive errors. In one such technology, unpolymerized photosensitive silicone macromers can be made to move down their concentration gradient after treating a special silicone IOL with ultraviolet light. After the desired spherocylindrical adjustment is achieved, remaining photosensitive macromers are consumed with an ultraviolet lock-in treatment.

In another technology that is not commercially available, the chemistry of an acrylic IOL is changed by a femtosecond laser with high spatial sensitivity to effect a change in hydrophilicity. The resulting change in local chemistry induces a change in water content and a corresponding alteration in the material's focal refractive index. The technology, known as refractive index shaping, can be applied across an IOL to produce changes in sphere, cylinder, and the number of focal points.[678-680] Theoretically, it might be possible to apply wavefront error compensation as well. This technology has the potential for multiple treatments over time. Other technologies being investigated include multicomponent IOLs, mechanically adjustable IOLs, magnetically adjustable IOLs, and liquid crystal IOLs.[677]

Capsular Bag Fixation

The capsular bag is the best location to fixate an IOL. However, noncapsular bag fixation may be necessary if there are zonular abnormalities or anterior or posterior capsular tears. The surgeon should have backup IOLs available to handle these occurrences. Options include anterior chamber IOLs or posterior chamber IOLs that can be positioned with or without active fixation within the ciliary sulcus.[681-685] Optic capture or reverse optic capture through a capsulorrhexis opening, if possible, may help center an IOL.[686] Suturing posterior

chamber IOL haptics to the iris or sclera may be necessary in the absence of capsular support.[681-685] Certain unique IOL designs, such as plate haptic IOLs, require capsular-bag fixation. In the event of posterior capsule rupture, the surgeon should reconsider capsular IOL implantation without proper posterior capsular support and use an alternative IOL style. No single method of noncapsular-bag fixation has been found to be superior. All appear to be equivalent with respect to visual acuity and safety profile. Each type of fixation has its own specific risks.[687]

Alternatives to Capsular Bag Fixation

Active and passive alternative techniques of IOL fixation can be used when capsular bag or zonular support is insufficient. Appropriately designed IOLs can be passively secured in the ciliary sulcus or anterior chamber. Suitable IOLs can be actively fixated to the iris or sclera as an alternative.

Sulcus fixation

Optimal characteristics of a sulcus posterior chamber IOL include sufficient overall optic diameter and haptic length, posterior haptic angulation, and the absence of sharp anterior optic or haptic edges.[685] Anticipating a more anterior location of the optic, the sulcus IOL power for the average eye should be decreased by 0.5 diopters (D) to 1.0 D relative to that calculated for capsular bag fixation (but decreased less with capsulorrhexis capture of the optic).[688, 689] Optic capture through a centered capsulorrhexis reduces reliance on adequate haptic length to provide optic centration and stability.[690, 691] Because noncapsular fixation increases the potential for optic tilt and decentration, the surgeon should reconsider whether multifocal IOLs or IOLs with higher degrees of negative spherical aberration should be implanted.[607, 692] Also, single-piece acrylic IOLs currently available in the United States are contraindicated in the ciliary sulcus because of associated risks such as IOL decentration and iris chafing, which can cause transillumination defects, pigment dispersion, elevated IOP, recurrent hyphema, and inflammation.[685]

Suture fixation of one or both haptics of a posterior chamber IOL to the iris or sclera is an option in the absence of sufficient capsular support.[681-685] Risks include improper anatomic placement and suture breakage or knot unraveling.[693-697]

Iris suture fixation

Suturing a posterior chamber IOL to the posterior aspect of the iris is an option for IOL fixation in the setting of a ruptured posterior capsule or inadequate sulcus support, or for a secondary implantation in an aphakic eye, or for correcting IOL dislocation. Surgical time is usually shorter than for scleral fixation, but postoperative inflammation may be higher.[698] Possible complications include recurrent IOL dislocation, dyscoria, postoperative IOP elevation, CME, epiretinal membrane development, and postoperative inflammation.[698, 699] The implantation of iris-claw IOLs is an alternative in countries where they are commercially available.[700-702]

Sutured inner scleral, intrascleral, or transscleral fixation

The inner scleral approach involves ab externo or ab interno fixation of the haptics of a posterior chamber IOL to the sclera using nonabsorbable sutures. The most common complications include recurrent IOL dislocation, tilt, intraocular hemorrhage, and RD. There is also a risk of suture knot exposure, erosion or breakage, and glaucoma.[698, 703]

Intrascleral fixation appears to be an effective and safe technique in the absence of capsular support, and studies have found good positioning of the IOL and insignificant tilt over a relatively short period of time.[704, 705] Haptics may be placed in scleral pockets with or without fibrin glue. However, long-term studies to evaluate glue use are lacking. Possible complications include haptic deformation and breakage, IOL decentration and dislocation, intraocular hemorrhage, glaucoma, CME, optic capture, and RD.[703]

Transscleral fixation refers to the Yamane technique and its variants.[706-708] The haptics of the IOL are externalized through the sclera and conjunctiva, and the haptic ends are

cauterized to create a flange. The flanged haptic ends are then tucked subconjunctivally into their respective scleral tunnels. Complications include ocular hypertension, IOL tilt, optic capture, vitreous hemorrhage, CME, haptic erosion through the conjunctiva, and endophthalmitis.[703, 709]

Anterior chamber fixation

Effective use of an anterior chamber IOL depends on appropriate IOL design, sizing, and placement. Iris deformity, pupil distortion, corneal endothelial failure, and ocular discomfort may result from an IOL that is too long, whereas rotation and movement of an IOL that is too short may induce chronic inflammation, CME, and corneal endothelial damage.[685] White-to-white corneal diameter measurement in the horizontal meridian has been found to be the most accurate way to estimate proper anterior chamber IOL length if anterior chamber OCT is unavailable. An anterior chamber IOL should be oriented with its haptics away from the incision to prevent early haptic prolapse.[710] A peripheral iridectomy should be fashioned to prevent pupillary block.[711] A 2018 network meta-analysis[712] supports the efficacy of all three methods of IOL fixation—iris, transscleral and intrascleral —in the absence of adequate capsular support. *(I+, Good, Strong)*

Outcomes

Multiple large studies of cataract surgery, including a review of the Cochrane Library, have repeatedly demonstrated favorable outcomes from cataract surgery.[713] *(I+, Good, Strong)* While there are many earlier outcome studies,[714] a 2013 European Registry of Quality Outcomes for Cataract and Refractive Surgery examined 368,256 surgeries from surgeon dataset entries, national registries, and electronic medical record systems. It reported 94.3% with 20/40 or better CDVA and 61.3% with 20/20 or better CDVA.[112] Only 1.7% had worse CDVA postoperatively, with the greatest risk factors being a postoperative complication, ocular comorbidity, or surgical complication.

A study that accessed 2013 and 2014 Intelligent Research in Sight (IRIS®) registry data reported 81.7% of 33,437 eyes having CDVA of 20/40 or better by postoperative month 1.[715] A large multicenter study in the United Kingdom showed that over 95% of eyes with no ocular comorbidity had a CDVA of 20/40 or better.[716]

The Cataract Patient Outcomes Research Team (PORT) study identified independent predictors for greater improvement after surgery that included younger age (under 65), less comorbidity, a higher cataract symptom score, and a worse VF-14 (visual function) score.[168] In several studies, preoperative Snellen visual acuity was found to be unrelated to the likelihood of improvement in symptoms or self-reported visual function after cataract surgery.[168, 171, 717] A prospectively validated model found that predictors of improvement included younger age, a poorer preoperative visual function as measured by the ADVS, and absence of diabetes.[717] However, even patients with diabetes and age-related macular degeneration (AMD) show substantial improvements after cataract surgery, albeit at a lower magnitude than patients without these conditions.[718-722] There is no evidence that AMD accelerates following cataract surgery.[723] Although these studies have shown greater benefits in younger patients, the improvement in quality of life for those 75 and older is still functionally and statistically significant.

Another study used a validated visual function questionnaire and a variety of psychophysical methods to assess visual improvement in patients with symptomatic cataracts but with preoperative Snellen acuity better than or equal to 20/50.[724] Even in eyes with 20/20 or better preoperative Snellen acuity, cataract surgery improved patients' self-reported visual impairment.[171] Neither the preoperative best corrected high-contrast Snellen distance acuity nor change in Snellen acuity predicted the observed improvement in visual function as reflected in the preoperative and postoperative questionnaire scores. The strongest preoperative indicators for improved visual function were glare disability tested at low and medium spatial frequencies and the visual function questionnaire score. This suggests that in patients with symptomatic nonadvanced cataract, Snellen visual acuity in isolation does not accurately predict who will benefit from surgery.[725]

Cataract surgery improves driving safety. There is an increased risk of motor vehicle accidents in patients with cataract and a significant reduction after cataract surgery.[726]

Multiple papers on FLACS show results similar to standard ultrasonic phacoemulsification.[527, 727, 728] They also confirm the generally excellent results of modern cataract surgery. The ESCRS FLACS study compared 2814 consecutive cases from high-volume FLACS surgeons with 4987 control patients matched by age, preoperative CDVA, ocular comorbidities, and surgical comorbidities from the 2014 European Registry of Quality Outcomes for Cataract and Refractive Surgery. The control group had better postoperative CDVA (logMAR 0.03 vs. 0.05, $P < 0.05$) and a statistically significantly higher likelihood of being 20/20 or better (76.1% vs. 70.8%) or 20/25 or better (90.4% vs. 87.8%) and a lower likelihood of worse CDVA than preoperatively (0.4% vs. 1.0%).[728] The mean refractive error was 0.40 D versus 0.43 D for FLACS, $P < 0.05$, with 74.3% of control eyes being within 0.5 D and 94.1% being within 1 D of target.

The French Ministry of Health-sponsored femtosecond laser-assisted versus phacoemulsification cataract surgery (FEMCAT) prospective, multisite, randomized controlled trial enrolled 909 patients for bilateral FLACS or manual phacoemulsification. A sham docking procedure was performed on manual eyes. The FEMCAT trial defined success as no intraoperative or postoperative complications within 3 months; a UDVA of 20/20 or better at postoperative month 3, an absolute refractive error of 0.75 D or less, and surgically induced astigmatism of 0.5 D or less.[727] The success rate was 41.1% for FLACS and 43.6% for manual surgery (odds ratio 0.85, 95% CI 0.64–1.12, $P = 0.250$). Another randomized controlled trial of 400 eyes found no significant difference between femtosecond and manual cataract surgery. The laser group had a lower posterior capsule rupture rate, but the rate of 3% in the manual group was higher than in the other studies.[729]

Complications of Cataract Surgery

Although numerous complications can occur intraoperatively or postoperatively, those resulting in permanent loss of vision are rare. Major complications that are sight-threatening include infectious endophthalmitis, TASS, TPSS, suprachoroidal hemorrhage, CME, RD, persistent corneal edema, IOL dislocation, secondary glaucoma, diplopia, and blindness.

The Cataract PORT study reviewed the incidence of cataract complications from studies published prior to 1992 and with an overall phacoemulsification/manual ECCE case mix of 2:1.[730] Six subsequent studies of adverse perioperative outcomes from cataract surgery are summarized in Table 3. In one of these studies, Greenberg et al[731] reviewed the incidence of complications from cataract surgeries performed at the U.S. Veterans Health Administration system from 2005 to 2007. The most common ocular complications were posterior capsular tear, anterior vitrectomy, or both during surgery (3.5%), and PCO after surgery (4.2%). Of note, many surgeries in this setting are performed by residents in training.

TABLE 3   COMPLICATION RATES FROM SELECTED STUDIES OF CATARACT SURGERY

	Cataract PORT, 1994[730]	Schein et al, 1994[113]	NEON, 2000[732]	Zaidi et al, 2007[733]	Jaycock et al, 2009[716]	Greenberg et al, 2011[731]	Clark et al, 2011[734]	Pershing et al, 2019[364]	Mahr et al, 2020[735]
Number of cases	*	717	2603	1000	55,567	45,082	65,060	8,542,838	2,267,182
Percent phacoemulsification	65	65	92	100	99.7	95 (approx)[†]	100		
Intraoperative (%)									
Posterior capsular or zonular rupture	3.1	1.95	1.6	1.5	1.92[‡]	3.5[§]	NA	NA	NA
Vitreous loss/ anterior vitrectomy or aspiration	0.8	1.39	1.1	1.1	NA	NA	NA	NA	NA
Iris/ciliary body injury	0.7	0.84	0	1.2	0.55	0.1	NA	NA	NA
Loss of nuclear material into vitreous	NA	0.28	<1	0.1	0.18	0.2	0.16	NA	NA
Suprachoroidal hemorrhage	NA	0.14	0	0	0.07	0	NA	NA	NA
Retrobulbar hemorrhage	NA	0	0	0.1	NA	0	NA	NA	NA
Postoperative (%)					(n = 16,731)[‖]				
CME	3.5	3.21	NA	1.2	1.62	3.3	NA	NA	NA
Iris abnormalities	1.3	2.51	NA	NA	0.16	NA	NA	NA	NA
Corneal edema	NA	1.95	<1	0.7	5.18	NA	0.03	NA	NA
Wound leak or rupture	NA	0.84	<1	1.1	0.14	NA	0.06	NA	NA
IOL dislocation, removal, or exchange	1.1	0.28	<1	NA	0.22	0.9	0.19	NA	NA
Endophthalmitis	0.13	0.14	<1	0.1	NA	0.2	0.17	0.04	NA
Retinal tear, break, or detachment	0.7	0.14	<1	0.2	NA	0.9	0.37	NA	NA
Visually significant CME	NA	NA	<1	NA	NA	NA	NA	NA	NA
Persistent iritis	NA	NA	1.1	1.1	NA	NA	NA	NA	NA
Retained lens fragment requiring return to OR for removal								NA	0.18

CME = cystoid macular edema; IOL = intraocular lens; NA = not available; NEON = National Eyecare Outcomes Network; OR = operating room; PORT = Cataract Patient Outcomes Research Team.

* Number of cases varies depending on the studies included for each complication.

† The study used Current Procedural Terminology codes to identify cases that do not specify whether cataract surgeries are performed by phacoemulsification or manual extracapsular cataract extraction. A survey[736] of Veterans Health Administration facilities found that phacoemulsification was performed in approximately 95% of extracapsular cataract surgeries.

‡ This is a composite figure that includes posterior capsule rupture without vitreous loss, posterior capsule rupture with vitreous loss, and zonule rupture with vitreous loss.

§ This is a composite figure that includes diagnostic codes for posterior capsule tear and procedural codes for anterior vitrectomy.

‖ Postoperative information was not available for all study patients.

Stein et al[737] stratified Medicare beneficiaries who underwent cataract surgery into three cohorts: those who had their first cataract surgery in 1994–1995 (n = 57,780), 1999–2000 (n = 73,064), or 2005–2006 (n = 90,750). The overall rate of severe complications in the 1-year postoperative interval was 0.5%. Severe complications were defined as endophthalmitis (0.16%), suprachoroidal hemorrhage (0.06%), and RD (0.26%). The occurrence of a severe complication declined over time from 0.6% in the earliest cohort to 0.4% in the most recent group.

A study performed in the United Kingdom reported a 9% complication rate in the overall rate of complications after phacoemulsification.[733] Of the complications reported, 2% were considered major, including vitreous loss (1%), lens drop (0.1%), iris trauma (1%), RD (0.2%), and endophthalmitis (0.1%). Less severe complications included wound leak (1%), prolonged corneal edema (0.7%), uveitis (1%), and persistent elevated IOP (0.3%). A 2015 study showed similar results.[738]

Specific complications following cataract surgery are discussed below.

Incision complications

An incision that is not watertight can lead to several complications, including postoperative wound leak, hypotony, and endophthalmitis.[382] An incision that is too large will cause leakage of fluid from the wound and destabilize the anterior chamber during surgery. An incision that is too tight dramatically increases friction, which increases the heat from the ultrasonic phacoemulsification needle and increases the risk of wound burn. Wound burn (ultrasound stromal thermal damage) occurs at 60° C or higher.[739] A survey identified 419 cases of wound burn, which yielded an incidence of 0.043%.[740] In a multivariable analysis, factors associated with this problem in order of decreasing significance were lower surgical volume, surgical technique, and type of OVD used.[740] The risk of wound burn varies among different OVDs.[741] Clearing viscoelastic to create a working space before beginning phacoemulsification of a cataract can help prevent burns. Thermal injury can result in incisions that are difficult to close. Burn-induced astigmatism may affect refractive outcomes, particularly with new-technology IOLs.

An incision that is not self-sealing at the end of the surgery will require sutures or adhesive for proper closure. The risk of perioperative wound leak (e.g., risk increased with eye rubbing, poor scleral rigidity) is another consideration for the use of sutures or eye protection postoperatively. Sutures can induce postoperative astigmatism, the magnitude of which is dependent on their location and tension.[537, 742] The induced astigmatism is usually reversed upon suture removal.[743, 744]

Iris complications

Iris injury induced by cataract surgery can be classified according to location. Iris sphincter damage at the pupillary margin may cause mydriasis and an irregular pupil. Mid-peripheral defects are located peripheral to the sphincter but do not extend to the iris root. Iridodialysis involves disinsertion of the iris from the internal wall of the eye.[745] Damage to the iris can result from iris prolapse due to conditions such as intraoperative floppy iris syndrome (IFIS)[746, 747] or a poorly constructed incision. Causes of surgical iris trauma due to a shallow chamber may include iris aspiration or agitation from the phacoemulsification tip, sphincterotomies, and excessive stretching or manipulation from expansion devices (iris hooks and rings) and instruments. The sequelae of such trauma may include iridodialysis; hyphema; transillumination defects; traumatic mydriasis; and an irregular, atonic, or misshapen pupil.[745] Sphincter necrosis may occur perioperatively as a result of endophthalmitis, TASS, or excessively increased IOP that may result in a chronically dilated or irregular pupil.

Corneal complications

Improper instrument entry into the anterior chamber can lead to Descemet membrane tears or detachment.[748, 749] Femtosecond laser-assisted cataract surgery is also known to produce small Descemet membrane detachments.[750] A small tear may require no attention, since such tears often spontaneously resolve. Larger tears can be repaired by repositioning and tamponading the flap of Descemet membrane with a gas bubble or sutures. The corneal

endothelium is susceptible to damage from any mechanical injury and from prolonged ultrasonic power. It can also be damaged by intraocular solutions that have a nonphysiologic osmolarity or pH, or by chemical insult from toxic contaminants or improperly formulated intraocular solutions and medications.[479, 483] Prolonged elevated IOP can lead to further endothelial decompensation and corneal edema. The surgeon should avoid working close to the cornea and orient irrigation ports away from the corneal endothelium. Replenishing dispersive OVD during prolonged phacoemulsification or in the presence of several smaller shards of brunescent cataract can also help protect the corneal endothelium. Fuchs endothelial dystrophy and other corneal pathologies may predispose to prolonged corneal edema after surgery and, if severe with no improvement over time, may require corneal endothelial transplantation.

Patients with a history of Herpes simplex virus stromal keratitis should receive perioperative antiviral prophylaxis to avoid postoperative recurrence.

Inflammation

Prolonged inflammation

There are several potential etiologies for prolonged postsurgical inflammation. Prolonged inflammation, or iritis, is defined as inflammation that does not resolve within a few weeks of cataract surgery. This is in contrast to rebound inflammation, which is inflammation that resolves in the usual time frame but then recurs. Persistent iritis has been associated with herpetic eye disease, retained lens fragments,[751] previous history of uveitis,[752] and a subacute infection with *Propionibacterium acnes*.[753] Gonioscopy may be necessary to see small lens fragments in the inferior angle. Ultrasound biomicroscopy, long-wavelength OCT, or endoscopy may be needed to identify lens fragments trapped in the ciliary sulcus. Other infectious agents, such as fungi, can cause indolent infection and inflammation. Malposition or misplacement of IOLs of specific design may also lead to persistent intraocular inflammation, such as a malpositioned anterior chamber IOL or a one-piece acrylic IOL placed in the ciliary sulcus. The surgeon should ensure proper orientation of IOLs to prevent corneal complications. Insufficient postoperative anti-inflammatory medication may also be a contributory cause.[754] Diabetic patients and patients who required a pupil expansion device at the time of surgery are at increased risk of persistent postoperative inflammation.[755, 756] These patients are also at increased risk for developing CME, up to 29.5% in one study. However, long-term outcomes are still equivalent to patients without prolonged inflammation.[755, 756]

Rebound inflammation

Discontinuation of corticosteroid eye drops after cataract surgery may be followed by a recurrence of inflammation, resulting in increased cell and flare or CME. Reinstituting anti-inflammatory eye drops will decrease the inflammation and may require a slower taper to prevent reappearance.

Endophthalmitis

According to peer-reviewed literature, the incidence of postoperative endophthalmitis ranges from 0.04% to 0.2% in the United States,[113, 364, 367, 379, 715, 731] and from 0.02% to 1.16% elsewhere according to other English-language peer-reviewed literature.[387, 443, 730, 732, 734, 737, 757-763] *Staphylococcus epidermidis* is the most common pathogen.[757, 759] Risk factors for endophthalmitis after cataract surgery include posterior capsular rupture (up to 10-fold increase),[379, 382, 387, 388, 763] older age,[387] relative immunodeficiency,[379] resident-performed cataract surgery,[388] wound leak on the first postoperative day,[382] inferior incision location,[379] longer surgery,[764] topical anesthesia,[764] and the use of topical lidocaine gel before povidone iodine application.[379] The absence of intracameral cefuroxime administration in the European endophthalmitis study was associated with a statistically higher rate of postoperative endophthalmitis.[424]

The type and size of incision (clear corneal vs. sclera) has been implicated as a possible factor in the development of endophthalmitis.[372] However, several articles found no conclusive evidence for an association between clear corneal incision and endophthalmitis.[379, 765, 766]

As mentioned earlier in the Infection Prophylaxis section, two pharmacologic interventions have been shown to reduce the rate of postoperative endophthalmitis conclusively in clinical trials. They include treating the eyelids and conjunctival cul de sac with povidone iodine immediately before surgery and injecting cefuroxime into the anterior chamber at the conclusion of surgery.[406, 407, 424, 432, 767-770] Moxifloxacin injection is currently popular in the United States even though it lacks randomized, prospective clinical trial evidence.

For a detailed discussion of endophthalmitis prophylaxis, please refer to the Infection Prophylaxis section.

Patients who develop endophthalmitis may present with complaints of decreased vision, pain, redness, new floaters, and eyelid edema.[771, 772] Although, the onset of symptoms was historically considered to occur during the first postoperative week,[773-775] newer studies report delayed onset of up to several weeks.[379, 776] Patients should be encouraged to call their surgeon if they experience pain or worsening vision. Common findings include conjunctival injection, corneal edema, anterior chamber inflammation, fibrin, hypopyon, and vitritis.[771, 772] Endophthalmitis must be differentiated from TASS and TPSS, which have slightly different time courses and require completely different treatments.

If endophthalmitis is suspected, referral to a retina specialist is appropriate. If a retina specialist is unavailable within 24 hours, the anterior or posterior segment should be tapped by any experienced ophthalmologist, including the cataract surgeon, for evaluation of possible pathogens, followed by intravitreal injection of antibiotics.[773] The Endophthalmitis Vitrectomy Study (EVS) recommended an intravitreal tap plus injection of antibiotics in patients who present with vision of hand motion or better. Conversely, patients who present with vision of light perception or worse are more successfully treated by means of pars plana vitrectomy and antibiotics.[773]

Posterior capsular tear or zonular rupture

Reported rates of posterior capsular tear or zonular rupture average around 2% in low-risk cases and up to 9% in patients with a history of pars plana vitrectomy.[716, 732, 777-779] Additional risk factors for posterior capsular tear with or without vitreous loss include older age, male gender, glaucoma, diabetic retinopathy, brunescent or white cataract, posterior polar cataract, inability to visualize the posterior segment preoperatively, pseudoexfoliation (exfoliation syndrome), small pupils, axial length greater than 26 mm, use of systemic alpha-1a antagonist medication (e.g., tamsulosin), previous trauma, inability of the patient to lie flat, history of intravitreal injections, patient movement, and resident-performed cataract surgery.[780-782] Maintaining a stable anterior chamber and a well-dilated pupil are two factors a surgeon can control to reduce risk. Early adopters of femtosecond lasers for lens fragmentation experienced a higher rate of capsular rupture.[783] However, recent reports have not confirmed these higher rates. According to both the FEMCAT and FACTS studies, randomized, controlled trials that compare FLACS with conventional cataract surgery, there were no differences in the rate of posterior capsular rupture between the two groups.[727, 784] Intraoperative risk factors include loose zonular fibers, a need for capsular stain, and miosis.[781] The factors listed here are some of the known risks, but posterior capsular and zonular complications may occur without any obvious predisposing factors.

Dropped lens fragments

The incidence of lens fragments dropping into the posterior segment is 0.1% to 0.28%.[716, 730] If there is vitreous displacement, the surgeon should perform a vitrectomy if comfortable or refer immediately to a retina specialist.[785] The use of injected triamcinolone may aid in visualization of vitreous.[786] Because there is an increased risk of inflammation and elevated IOP, consideration should be given to referring patients with dropped nuclear lens fragments to a retina surgeon once the cornea has cleared.[787]

The most appropriate timing of a secondary pars plana vitrectomy is unclear, but the eye should be carefully monitored for complications, such as elevated IOP and inflammation.[788-790]

Retinal detachment

Overall rates of RD range from 0.26% to 4%.[734, 737, 766, 791-796] Risk factors for the development of RD after cataract surgery include moderate to high axial length, posterior capsule tear, vitreous loss, younger age, male gender, lattice retinal degeneration, zonular dehiscence, RD in the fellow eye, and the new onset of a postoperative posterior vitreous detachment.[766, 791-796] In one study, the mean interval between cataract surgery and RD was 39 months,[796] but the increased risk of RD in pseudophakic eyes may continue for as long as 20 years.[797] There was no statistically significant difference in the probability of RD after phacoemulsification compared with ECCE.[797]

Suprachoroidal hemorrhage

Historically, the incidence of suprachoroidal hemorrhage related to large-incision cataract surgery was reported to be 0.15% to 0.19% and to be associated with myopia, glaucoma, diabetes, atherosclerotic vascular diseases, hypertension, and prolonged intraoperative hypotony.[798] Published data on the incidence of suprachoroidal hemorrhage following phacoemulsification are lacking. The risk is probably lower because the surgical duration is shorter and the hypotony time is reduced. Suprachoroidal hemorrhage has been reported during FLACS.[799] The majority of published studies support the continuation of anticoagulant and antiplatelet therapy during cataract surgery.[800] Anticoagulation with warfarin does not significantly increase the frequency of (supra)choroidal hemorrhage.[801]

Clinical signs and symptoms of an intraoperative (supra)choroidal hemorrhage include sudden pain, scotoma and loss of red reflex, elevated IOP, shallowing of the anterior chamber, and iris prolapse.[802] Prompt diagnosis of a hemorrhage and immediate incision closure minimizes the likelihood of sight-threatening complications.

Cystoid macular edema

Clinically significant CME occurs infrequently after routine, uncomplicated phacoemulsification (1%–3%)[716, 731, 733] and often responds well to topical anti-inflammatory medication; however, recalcitrant cases (0.02% of cases) may be associated with permanent impairment of visual acuity. Risk factors for CME include previous uveitis, posterior capsule rupture with vitreous loss, retained lens material, diabetic retinopathy, venous occlusive disease, epiretinal membranes, prior vitreoretinal surgery, nanophthalmos, retinitis pigmentosa, radiation retinopathy, male gender, older age, and a history of pseudophakic CME in the fellow eye.[803] Anatomic diagnosis is frequently made using OCT, a less invasive technique than fluorescein angiography. Snellen visual acuity may underestimate the impact of CME on visual function.

Because CME is generally associated with postsurgical inflammation, topical anti-inflammatory medications are used to prevent it and to treat established CME. There is evidence that nonsteroidal anti-inflammatory drugs (NSAIDs), alone or in combination with topical corticosteroids, decrease the likelihood of postoperative CME, especially in diabetics.[804, 805] *(I+, Good, Strong)* Studies show a short term benefit in visual recovery, but no level I evidence yet of long-term benefit (i.e., 3 months or more).[806, 807] The 2018 ESCRS PREMED randomized clinical trial compared bromfenac 0.09% twice a day with dexamethasone 0.1% four times a day versus a combination of the two. The study found that patients receiving the combination had a lower incidence of CME after cataract surgery than patients treated with either medication alone.[808]

The use of intravitreal anti-angiogenesis agents at the time of cataract surgery for prophylaxis or treatment of select cases of CME is being investigated.[809] In the PREMED 2 study, patients were randomized to receive 40 mg of subconjunctival triamcinolone acetonide, a 1.25mg injection of bevacizumab, a combination of both, or no treatment. The study found that subconjunctival triamcinolone decreased macular thickness and volume at

6 to 12 weeks and that intravitreal bevacizumab had no effect. In another study of patients with stable diabetic retinopathy without macular edema, injections of ranibizumab reduced the incidence of postoperative CME in the study group.[810]

At present, there is no firmly established protocol for preventing postsurgical CME. Aside from retinitis pigmentosa, there are no known genetic predispositions. The perioperative prophylactic use of NSAIDs for the prevention of CME has been advocated for high-risk eyes based on a number of studies.[803, 811] Administration of NSAIDs before and immediately after surgery may hasten the recovery of vision in the first few weeks following surgery.[812] Again, there is no level I evidence that long-term visual outcomes are improved by the routine use of prophylactic NSAIDs at 3 months or more after cataract surgery.[813] Anti-vascular endothelial growth factors and intravitreal corticosteroids may be useful, especially in diabetics, when topical medications fail or produce limited results.[812, 814, 815]

Elevated Intraocular pressure

Transient elevation of IOP is commonly encountered during the early postoperative period. Although it rarely causes permanent injury, acute postoperative IOP elevation can cause nausea and pain and induce microcystic corneal edema. The long-term impact of postoperative IOP spikes is unknown and could be a subject for future study. Some eyes may be more susceptible to optic nerve damage or retinal vascular occlusion. The likelihood of IOP elevation increases if a patient has a history of glaucoma and/or if OVD is left in the eye, including behind the IOL, at the conclusion of surgery. Therefore, thorough removal of OVD is recommended.[816] Dispersive OVDs are more likely than cohesive OVDs to be retained because they adhere more to intraocular structures. The optimal pharmacological regimen for preventing an immediate postoperative IOP spike is unclear. It appears that topical aqueous suppressants, oral carbonic anhydrase inhibitors,[817, 818] and intracameral carbachol are beneficial.[819-838] Topical corticosteroid use may elevate IOP in eyes that are "corticosteroid responders."[839] Difluprednate 0.05% is more likely to elevate IOP than prednisolone acetate 1%, and steroid-induced pressure elevation is more likely to occur in patients who are younger, highly myopic, or have glaucoma or pseudoexfoliation.[840-842] Corticosteroid cessation usually results in a reduction of the IOP to normal levels, and IOP should be monitored in patients treated with corticosteroid medication postoperatively.[839] The desire to control IOP elevation must always be balanced against the need to control postoperative inflammation.

Complications of Intraocular Lenses

Incorrect intraocular lens power

Incorrect IOL power may necessitate an IOL exchange. A preoperative "Time Out" that includes the surgical staff in the operating room can help avoid placement of a wrong IOL. Incorrect IOL labeling, transcription errors, or mistakenly implanting the wrong IOL may result in an unwanted refractive surprise. Preoperative measurement error may occur with uncooperative patients, post-refractive surgery eyes, and atypical anatomic variations such as staphylomas (see Biometry and Intraocular Lens Power Calculation section and sections that discuss cataract surgery following prior keratorefractive surgery). Finally, surgical factors that can affect the postoperative position of the IOL (the effective lens position), and thus the postoperative refractive state, include retained OVD, capsular block, improper haptic or optic placement, and upside-down placement of the IOL. A three-piece IOL with angulated haptics that is placed upside down or in the sulcus will result in a myopic shift from an anteriorly displaced optic. Aqueous misdirection into the vitreous cavity can also result in anterior displacement of an optic.

When an unacceptable or intolerable refractive error results following IOL implantation, the risks of surgical intervention must be weighed against the alternatives of eyeglass or contact lens correction. Surgical alternatives to IOL exchange include keratorefractive surgery and secondary piggyback IOL implantation.

Damaged intraocular lens

Rarely, an IOL will be damaged during the insertion process or a laser capsulotomy. When IOL defects are visually significant, the ophthalmologist must weigh the risks and benefits of IOL exchange.

Decentration

Intraocular lens decentration or subluxation has been reported with virtually all IOL materials and models, including both one-piece and three-piece designs.[843] This complication is seen most commonly when the haptics are not placed symmetrically inside the capsular bag or when an IOL is placed in a bag with a capsular tear and the optic is not fixated within an intact and centered capsulorrhexis. Major predisposing factors for IOL subluxation in one study were secondary implantation, posterior capsule rupture, and mature cataract.[844] Posterior chamber IOL decentration can result from damaged haptics, zonular dialysis, anterior or posterior capsular tears, asymmetric capsulorrhexis, asymmetric contraction and fibrosis of the capsular bag, and asymmetric placement of the haptics with one in the ciliary sulcus and the other in the capsular bag. Asymmetric haptic placement can cause visual complaints, including edge glare, blur from high-order aberrations, inflammation associated with uveal irritation, secondary glaucoma, and hyphema (see the Uveitis-glaucoma-hyphema syndrome section).[685]

Malposition

Toric IOLs may rotate after implantation, usually in the first few hours following surgery. Single-piece acrylic IOLs are more rotationally stable than early generation silicone plate-haptic IOLs, although malposition is seen occasionally and may depend on design.[845, 846] Improper positioning at the time of surgery, high myopia, anterior capsule polishing, retained OVD, and shifts in postoperative corneal astigmatism account for most cases of toric IOL misalignment.[847] Reoperation to reorient a toric optic on axis usually remedies this problem.[848]

Pseudo-accommodative lenses with flexible hinges are at risk of tilting or of a "Z syndrome" if the capsular bag is too small at the time of implantation or if it contracts aggressively following surgery.[849-851] Anterior capsule polishing and capsule tension ring (CTR) implantation may reduce the incidence of this problem.

Luxation

Delayed spontaneous in-the-bag posterior IOL luxation is associated with diffuse zonular insufficiency, such as with pseudoexfoliation (exfoliation), prior vitreoretinal surgery, or a history of trauma.[852-855] In one study of 86 consecutive cases, the onset of late dislocation occurred on an average of 8.5 years following uncomplicated cataract surgery and was most commonly associated with exfoliation syndrome.[855] Spontaneous bag-IOL dislocation can occur with all types of IOL materials, including PMMA, silicone, and hydrophobic acrylic one-piece and three-piece IOL designs.[855] There is no evidence that the implantation of a CTR reduces the risk of late dislocation of the capsular bag.[856-858]

Plate haptic silicone IOLs can dislocate posteriorly following laser capsulotomy and, rarely, they can dislocate spontaneously from capsular contraction.[859] The problem usually occurs many years after surgery and may happen even if large fixation holes are present in the haptics.[860]

Lens-related visual disturbances (dysphotopsias)

The term *dysphotopsia* has been used to describe a variety of unwanted visual phenomena encountered by pseudophakic patients.[861, 862] Positive dysphotopsias may include halos; ghost images; starbursts; and arcs, rings, or flashes of light that may ultimately interfere with visual function. Negative dysphotopsia refers to a thin, dark crescent in the temporal midperipheral field of vision. Initially, dysphotopsias were commonly reported with high-refractive–index hydrophobic acrylic IOLs with reflective square edges. However, they

have since been reported with many different IOL materials and designs, including silicone and hydrophilic acrylic IOLs.[563, 863-866] Certain optic design characteristics such as a square peripheral edge, flat anterior surface, smaller optic diameter, and multifocality are more likely to result in unwanted optical images.[864, 867-869] Complications such as IOL opacification, cracked or damaged optics, and IOL decentration may also cause dysphotopsias. Multifocal implants, in particular, are most often explanted because of "waxy" vision, glare, halos, other dysphotopsias, and blurred vision that cannot be corrected optically.[870]

As mentioned, negative dysphotopsia is commonly described as a dark crescent or curved shadow that can appear, similar to a scotoma or "horse blinder" in the midtemporal field of vision.[869, 871, 872] Negative dysphotopsia symptoms tend to diminish with time. In one study, the incidence of negative dysphotopsias was 15% on the first postoperative day, whereas 1 year after surgery, only 3% of patients without intervention reported them.[872] Implantation of a piggyback IOL or reverse capture of the existing optic (placing the optic anterior to the capsulorrhexis) appears to reduce the symptoms of negative dysphotopsia.[873] Although controversial, scleral or iris suture fixation of the haptics of a lens so that it sits more anteriorly in the posterior chamber may help.[874] Negative dysphotopsia may also be induced at the interface of the capsulorrhexis and the anterior surface of the IOL.[873, 875] Henderson reported that positioning one optic-haptic junction in the inferior temporal region resulted in a decrease in complaints of negative dysphotopsia.[876] The benefits of this simple maneuver have been corroborated by other studies.[877-879]

Opacification

In one recent study, optic opacification was the most common indication for IOL exchange.[880] However, the prevalence of IOL opacification or calcification may be decreasing, at least according to a survey of IOL explantation.[843]

Hydrophilic acrylic or silicone IOLs may make future surgery complicated.[881] Hydrophilic acrylic IOLs may calcify if air or gas tamponade is necessary subsequently, such as in pars plana vitrectomy, Descemet stripping endothelial keratoplasty (DSEK) or Descemet membrane endothelial keratoplasty (DMEK).[584, 882-885] In eyes at risk for corneal endothelial decompensation, it is prudent to choose another lens material. Silicone IOLs may become cloudy from adherent silicone oil in subsequent retinal surgery.[886] Rarely, hydrophobic acrylic IOLs must be explanted because of intolerable glistenings.[578]

Uveitis-glaucoma-hyphema syndrome

The uveitis-glaucoma-hyphema (UGH) syndrome is often associated with uveal irritation from IOLs, especially modern single-piece acrylic IOLs.[685] Thick square-edge haptics and a square-edge optic in the sulcus can cause pigment dispersion, iris transillumination defects, elevated IOP, recurrent inflammation and/or hemorrhage.[685] Pseudophacodonesis was a risk factor for UGH syndrome in a recent review of cases.[887] Ultrasound biomicroscopy and anterior segment OCT may be helpful in identifying lens-iris contact. Anterior chamber IOLs can also cause UGH syndrome if there is improper sizing, iris tuck following implantation, or rotation of a haptic through a peripheral iridectomy.[887, 888]

Ocular comorbidities

Preoperative ocular comorbidities may adversely affect the outcome of cataract surgery.[112, 717, 889] Many comorbid conditions are associated with the potential for reduced improvement in visual function or CDVA,[890-892] and the patient should be informed and counseled prior to surgery. This is particularly true if the patient is electing to receive a multifocal IOL. Comorbid conditions found in patients with cataracts and the special considerations associated with these conditions are listed in Table 4.

TABLE 4   SELECTED PREOPERATIVE OCULAR COMORBIDITIES

Comorbidity	Anticipated Complicating Factors
Amblyopia	• Reduced visual potential
Age-related macular degeneration[723, 893-899]	• Reduced visual potential • Unrecognized preoperative exudative disease
Diabetic retinopathy[900-907]	• Reduced visual potential • Unrecognized retinopathy • Progression of existing retinopathy • CME • Poorly dilating pupil • Neovascularization of the iris, neovascularization of the angle, and neovascular glaucoma
Epiretinal membrane[803, 908-912]	• Reduced visual potential • Visual distortion • CME
Fuchs corneal endothelial dystrophy[913]	• Reduced visualization during surgery • Prolonged postoperative corneal edema • Pseudophakic corneal decompensation • Reduced visual potential • Calcification of the lens surface if a hydrophilic acrylic IOL is implanted and an endothelial keratoplasty is performed subsequently
Glaucoma[914-925]	• Elevated postoperative IOP • Reduced function of prior filtering surgery • Reduced contrast sensitivity
Keratoconus[926-928]	• IOL power calculation inaccuracy • Possible need for a rigid contact lens for optimal visual acuity after surgery • Problems associated with implanting a toric IOL if irregular corneal astigmatism is significant
Ocular surface disease/Dry eye[929, 930]	• Chronic irritation and redness • Unstable ocular surface • Variable astigmatism and high-order aberrations • Fluctuating vision postoperatively
Pseudoexfoliation (exfoliation syndrome)[931-940]	• Intraoperative miosis • Zonular laxity or instability • Vitreous loss • Retained nuclear fragments • Elevated postoperative IOP • Accelerated PCO • Anterior capsulorrhexis contraction • IOL tilt and decentration • Late dislocation of IOL or of bag-IOL complex
Retinitis pigmentosa[941-943]	• Reduced visual potential • Zonular laxity • Capsulorrhexis phimosis • Preoperative and postoperative CME • Late decentration or dislocation of the bag-IOL complex
Retinopathy of prematurity[944, 945]	• Amblyopia • Intraoperative miosis • Traction RD • Loose zonular fibers
Strabismus[946-948]	• Amblyopia • Postoperative diplopia

Uveitis[756, 949-958]	• Posterior synechiae
	• Weakened zonular fibers
	• Protein and cellular deposits on the lens implant
	• CME
	• Secondary glaucoma
	• Prolonged postoperative inflammation

CME = cystoid macular edema; IOL = intraocular lens; IOP = intraocular pressure; PCO = posterior capsule opacification; RD = retinal detachment.

The presence and extent of AMD may be identified preoperatively using diagnostic instrumentation such as OCT and fluorescein angiography, which can assist in establishing realistic expectations. These tests, however, do not assist with the prediction of visual potential. There is considerable evidence that the risk of pre-existing AMD worsening following cataract surgery is low compared with its natural history.[959-962]

The status of coexisting diabetic retinopathy, particularly macular edema, may be evaluated using OCT, thereby directing a more vigorous approach to preoperative, intraoperative, and postoperative medical treatment, including the use of intravitreal injections.[810, 901, 963-969] Cataract surgery does not appear to increase the risk of progression of adequately treated proliferative diabetic retinopathy or macular edema.[903, 970] However, patients inadequately treated who have pre-existing diabetic macular edema (DME) are at increased risk for progression of DME following cataract surgery.[803, 901]

Because of the risk of corneal decompensation in the presence of corneal endotheliopathy, the surgeon may consider using dispersive OVDs along with optimizing machine parameters and surgical techniques that reduce cumulative ultrasound time, fluid movement through the eye, and endothelial trauma.[971, 972] When selecting IOL power, the potential hyperopic shift associated with endothelial replacement surgery should be considered.[973]

Pseudoexfoliation (exfoliation syndrome) is commonly associated with a small pupil and weak zonular fibers, which increase the risk of capsular rupture, retained nuclear fragments, and pseudophacodonesis.[938] An anterior chamber depth of less than 2.5 mm measured preoperatively may be indicative of zonular weakness and increases the risk of complications almost fivefold.[934] Because of the risk of late bag-IOL dislocation in these patients, larger capsulorrhexis, capsule polishing, and laser anterior capsule-relaxing incisions may be considered to prevent or treat anterior capsule contraction.[855, 856, 974] Although there is no evidence that implantation of a CTR reduces the risk of late-in-the-bag IOL dislocation, CTR implantation may facilitate its repair using the lasso suture technique.[975]

The optimal timing of cataract surgery in the presence of uveitis is a function of many factors.[976, 977] Inflammation should be inactive or at its best level of control possible, generally for 3 or more months prior to elective surgery.[957, 978, 979] Topical and/or periocular, intraocular, and systemic anti-inflammatory medications should be started prior to surgery. They are then used more frequently and for a longer duration following surgery. Intravitreal, periocular, or systemic administration of anti-inflammatory medication may also be considered.[980]

In addition to ocular comorbidities, other characteristics of the eye may be associated with a higher risk for intraoperative and postoperative complications. High-risk ocular characteristics include a history of previous eye surgery, special types of cataracts, very large and very small eyes, deeply set eyes, small pupils, anterior or posterior synechiae, scarred or cloudy corneas, zonular weakness or absence, prior ocular trauma, and the systemic use of alpha-1a antagonists. Each set of circumstances poses unique challenges (see Table 5). As with ocular comorbidities, patients with high-risk ocular characteristics should be informed about the specific impact of their condition on the expected course and outcome of surgery, along with options that may be considered if complications occur.

TABLE 5   HIGH-RISK CHARACTERISTICS FOR INTRAOPERATIVE AND POSTOPERATIVE COMPLICATIONS

High-Risk Characteristic	Anticipated Complicating Factors
Anterior megalopia	• Zonular laxity • Pigment dispersion (associated with elevated IOP) • RD
Corneal opacification[981]	• Reduced visibility • Worsening of corneal clarity
Deeply set eye, narrow lid fissure, or prominent brow[982]	• Reduced visibility • Poor access to the limbus • Pooling of irrigation fluid • Wound deformation and leakage
Dense brunescent nuclear cataract[983, 984]	• Concomitant zonular laxity and intraoperative miosis • Little cortex to protect the capsule during phacoemulsification • Increased phacoemulsification time with increased risk of postoperative corneal edema • Greater risk of thermal and mechanical injury to the cornea and iris with phacoemulsification • Increased risk of posterior capsule rupture and zonular dehiscence
High hyperopia[985-988] (with short axial length)	• Shallow anterior chamber with increased risk of endothelial trauma • Increased risk of iris trauma and prolapse • Difficulty calculating lens implant power • Intraoperative suprachoroidal effusion (particularly in nanophthalmic eyes) • Aqueous misdirection
High myopia[989-994]	• Anterior chamber depth fluctuation, possibly aggravated by periodic reverse pupillary block • Difficulty calculating lens implant power, especially with posterior staphyloma • Decreased ocular rigidity, difficulty sealing the wound • Increased risk of RD
Miotic pupil[781, 995]	• Poor visualization • Increased risk for capsule tear/vitreous prolapse • Increased risk for iris damage and prolapse
Posterior polar cataract[996-999]	• Defective posterior capsule • Increased risk of dropped nucleus
Posterior synechiae	• Intraoperative miosis • Prolonged postoperative inflammation • Inflammatory deposits on IOLs • Iris bleeding
Potential need for vitreoretinal surgery[584, 1000-1002]	• Silicone IOLs may compromise subsequent surgical visibility if posterior segment surgery or silicone oil is needed • Hydrophilic IOLs may opacify if a gas bubble is injected
Prior intravitreal injections[782, 1003-1005]	• Endophthalmitis • Posterior capsular rupture • Retained lens fragments

TABLE 5 High-Risk Characteristics for Intraoperative and Postoperative Complications (continued)

High-Risk Characteristic	Anticipated Complicating Factors
Prior keratoplasty[1006-1008]	• Poor visualization • Graft rejection or failure • Endothelial decompensation • IOL power calculation inaccuracy • Hyperopic shift in association with endothelial keratoplasty
Prior keratorefractive surgery[1009-1012]	• IOL power calculation inaccuracy • Transient hyperopic shift immediately after surgery in eyes with a history of radial keratotomy • Dehiscence of refractive keratotomy incision • Reduced visual potential due to irregular astigmatism • Corneal aberrations with glare and haloes
Prior PPV[1013-1016]	• Conjunctival scarring • Intraoperative anterior chamber depth fluctuation, especially severe deepening • Intraoperative miosis • Increased nuclear sclerosis • Increased frequency of posterior capsule plaques • Weakened lens capsule and zonular fibers
Prior scleral buckling surgery[1017, 1018]	• Change in axial length affects IOL power calculation • Conjunctival scarring • Increased risk of sclera perforation with injection anesthesia
Prior trabeculectomy or tube shunt surgery[919, 1019-1022]	• Increased filtration through the bleb during surgery • Decreased filtration or bleb failure after surgery • Postoperative hypotony • Zonular laxity • Aqueous misdirection
Relative anterior microphthalmos[1023, 1024]	• Damage to iris, cornea, and posterior capsule • IOL power calculation inaccuracy
Shallow anterior chamber[1025]	• Iris injury • Iris prolapse • Postoperative corneal edema • Aqueous misdirection
Use of systemic sympathetic alpha-1a antagonist medication for treatment of prostatic hypertrophy[1026, 1027] and other systemic conditions	• Poor pupillary dilation, intraoperative miosis, iris billowing and prolapse
White cataract (mature cortical cataract)[1028-1031]	• Difficulty performing the capsulorrhexis (capsule staining and femtosecond lasers may be helpful)[1032-1034] • Lens intumescence • Radial capsulorrhexis tear with extension to the posterior capsule
Zonular laxity or dehiscence (e.g., trauma)[781, 1035, 1036]	• Phacodonesis • Vitreous prolapse around the lens equator • Capsular rupture with retained lens fragments • Fluid misdirection syndrome • Postoperative lens implant decentration • Increased risk of radial capsulorrhexis tear • Capsular contraction with late IOL/capsular bag decentration or dislocation

IOL = intraocular lens; IOP = intraocular pressure; PPV = pars plana vitrectomy; RD = retinal detachment.

In handling high-risk eyes, several technique modifications and/or adjunctive devices should be considered.

Ophthalmic viscosurgical devices vary in rheologic properties that may be advantageous for certain higher risk cases.[1037] A specific OVD may be selected based on its characteristics in cases of corneal endothelial deficiency, shallow anterior chamber, intumescent cataract, and small pupil.[1037]

Capsular dyes to stain the anterior capsule may be considered in cases of a white or mature cataract, or where visibility is compromised.[1029, 1034]

Capsule tension rings can be useful adjunctive devices when zonular weakness is present, reducing the likelihood of intraoperative zonular separation and capsular complication,[1038] and they may improve postoperative IOL centration.[1039] In cases of more profound zonulopathy, other options include capsule retractors, a modified CTR or a capsular tension segment for scleral suture fixation.[1040]

When zonular strength is insufficient to hold an IOL stably within the capsular bag or ciliary sulcus, alternative methods of lens fixation must be considered. They include suture fixation to the iris or sclera, iris clip fixation, intrascleral or transscleral haptic fixation, or anterior chamber placement.

Intraoperatively, a variety of methods have been described to expand the small pupil. Pharmacologic methods include intracameral alpha-1 agonists such as epinephrine or phenylephrine.[1041] Mechanical methods include viscomydriasis, release of posterior synechiae, pupil stretching, mini sphincterotomies, iris retractors, and pupil expansion rings.[1042, 1043] Patients should be offered surgical repair of symptomatic iris defects caused by cataract surgery.[1044]

Intraoperative floppy iris syndrome is a unique small-pupil syndrome associated with iris billowing and prolapse as well as with progressive intraoperative miosis.[1026, 1045] It is associated with a higher rate of surgical complications, particularly when it is not recognized or anticipated.[1026, 1045-1048] Intraoperative floppy iris syndrome can be anticipated when a patient has a history of using oral alpha-1 antagonists (e.g., tamsulosin, terazosin, doxazosin, silodosin) and the herbal remedy saw palmetto. Pupil stretching and sphincterotomies are ineffective in these eyes, and pharmacologic approaches, viscomydriasis, and pupil-expansion devices, either alone or in combination, should be used to manage IFIS.[1026, 1045, 1046]

Systemic Comorbidities

Systemic comorbidities that may be of importance intraoperatively include diabetes mellitus, pulmonary dysfunction, cardiovascular dysfunction (e.g., poorly controlled blood pressure, heart failure), musculoskeletal disorders causing positional difficulties, tremor, severe hearing impairment, anxiety disorders, intellectual disability, dementia, and coagulopathies.[1049] For patients with complex medical conditions, it may be beneficial to coordinate care with the patient's primary care physician. Depending on the planned anesthesia and sedation, appropriate measures should be taken to stabilize and monitor the condition.

Not only is diabetes a risk factor for early cataract development,[19, 20, 37-39] but it also leads to poor intraoperative pupillary dilation, slowed ocular surface healing, and an increased risk of postoperative macular edema.[804, 1050-1054] In a study of 65,370 patients, patients with diabetes and no diabetic retinopathy achieved 20/20 vision at a rate similar to those without diabetes. However, patients with diabetic retinopathy were less likely to achieve CDVA of 20/20, but they gained as many lines of vision from phacoemulsification as those without diabetes.[805]

A 2009 meta-analysis found that patients taking warfarin while undergoing cataract surgery had a threefold increase (overall 9%–10% incidence) of nonclinically significant bleeding events compared with patients not on warfarin.[1055] The majority of bleeding events were self-limited and included hyphema or subconjunctival hemorrhage. There was no evidence that continuing warfarin had a negative impact on postoperative visual acuity. This analysis

included studies with patients undergoing ECCE as well as phacoemulsification and who had topical, sub-Tenon's, peribulbar, or retrobulbar anesthesia.

Similarly, an analysis of 48,862 surgeries from the U.K. Cataract National Dataset found that patients on warfarin or clopidogrel had an increased incidence of subconjunctival hemorrhage (3.7% warfarin, 4.4% clopidogrel, 1.7% nonusers) and complications from anesthetic blocks via sharp needle injection or sub-Tenon's cannula (6.2% warfarin, 8% clopidogrel, 4.3% nonusers).[801] However, there was no significant increase in potentially sight-threatening complications from local anesthetic or operative hemorrhage (hyphema, choroidal/suprachoroidal hemorrhage). In patients taking aspirin alone, there was no increase in hemorrhagic or anesthetic complications.

A study of 19,283 surgeries (74% of which included a peribulbar or retrobulbar block) found that patients who continued aspirin or warfarin did not have an increased risk for ocular hemorrhagic events (hyphema, vitreous hemorrhage, retrobulbar hemorrhage). No information was provided on subconjunctival hemorrhage or eyelid ecchymosis.[1056]

Data on the use of newer anticoagulants with cataract surgery are sparse.

An increasing number of patients are on dual antithrombotic medications. A recent study screened 141,213 emergencies referred to a university hospital. Three cases of grade IV retrobulbar hemorrhage were identified; two of these patients were on combined acetylsalicylic acid and clopidogrel and received retrobulbar injections.[1057] In contrast, the U.K. study of 48,862 cataract surgeries found no increase in anesthetic or hemorrhagic complications in patients on dual antiplatelet or combined aspirin/warfarin treatment who received blocks or sub-Tenon's anesthesia.[801]

In summary, several studies show a higher incidence of subconjunctival hemorrhage in patients undergoing cataract surgery while taking antiplatelet or anticoagulant medication,[801, 1055, 1058, 1059] but the available data do not show an increase in sight-threatening complications[801, 1056, 1058, 1059] or decreased postoperative visual acuity.[1055] Evidence-based guidelines recommend continuation of anticoagulants and antiplatelet medications in patients undergoing cataract surgery.[1060-1063] Management of these cases should still be tailored to the individual patient's situation.[1064, 1065]

There are no recommendations from either the American Heart Association[1066] or the American Academy of Orthopaedic Surgeons to prescribe systemic antibiotic prophylaxis for patients with artificial heart valves or joint prostheses who undergo cataract surgery.[1067]

Combined Surgery and Special Circumstances

Cataract surgery and glaucoma

Cataract surgery with IOL implantation results in a modest reduction of IOP.[713, 917, 1068-1070] Studies have found that the degree of IOP reduction is greater with higher preoperative IOP levels and that the benefit may last for several years.[920, 922, 924, 1071, 1072] A more recent prospective study found that older patients, eyes with shorter axial length, women, and those with glaucoma or pseudoexfoliation were more likely to benefit from this effect.[1073]

When a candidate for cataract surgery also has glaucoma, surgical treatment options include cataract and IOL surgery alone, combined cataract and glaucoma surgery, glaucoma surgery after cataract surgery, or cataract surgery after glaucoma surgery. Glaucoma surgical options include trabeculectomy, aqueous shunts, nonpenetrating glaucoma surgery, minimally invasive glaucoma surgery (MIGS), transscleral cyclophotocoagulation, and endocyclophotocoagulation.[1074] A Veterans Affairs retrospective cohort study showed that eyes with glaucoma are at increased risk for complications and have more modest visual outcomes after cataract surgery compared with eyes that do not have glaucoma.[1075]

Phacoemulsification combined with trabeculectomy provides good IOP control as well as improved CDVA with the potential benefits of protection against potential postoperative IOP spikes and long-term IOP control with a single operation.[1076-1078] However, there are some data suggesting that overall bleb survival rates and long-term IOP control may be diminished in a combined procedure versus a stand-alone trabeculectomy.[1033,1040] A 2015

Cochrane Systematic Review examined combined versus cataract surgery alone in patients with glaucoma and concluded that there was low-quality evidence that combined cataract and glaucoma surgery resulted in better IOP control at 1 year compared with cataract surgery alone. *(I-, Insufficient, Discretionary)* The authors suggested the need for further RCTs to further develop evidence-based therapeutic guidelines.[1079] In the absence of such guidelines, the decision to perform combined surgery rests with the surgeon and should be based on individual patient circumstances.

In the presence of a pre-existing filtering bleb, cataract surgery may diminish the effectiveness of the bleb.[919, 1020]

Cataract surgery with minimally invasive glaucoma surgery

A variety of minimally invasive techniques are available that can be performed in conjunction with or following cataract surgery.[1080] These include ab interno canaloplasty,[1081] ab interno trabeculotomy,[1082] endocyclophotocoagulation,[1083, 1084] and several generations of ab interno trabecular bypass microstents,[1085-1088] any of which can be performed or implanted at the time of cataract surgery. Compared with traditional filtering surgery with antimetabolite usage, these adjunctive technologies may reduce the risk of hypotony and bleb complications, but they may not lower IOP as effectively.[1089, 1090] A multicenter, randomized, single-masked, controlled clinical trial showed that IOP was clinically lower at 2 years in the trabecular bypass microstent plus cataract surgery group compared with the cataract surgery alone group, with no differences in safety.[1085] The best surgical option depends on a number of factors, including the patient's response to medical or laser surgical treatment of the glaucoma, the degree of optic nerve damage, changes in the visual field, severity of the cataract, and the surgeon's experience. A thorough discussion of the MIGS devices can be found in the Primary Open-Angle Glaucoma (POAG) PPP.[1091]

Cataract surgery and corneal disease

Combined cataract and endothelial transplant surgery

Cataract surgery in patients with coexistent endothelial dystrophy should be approached with careful patient consent and attention to which patients are most at risk of rapid progression. The presence of endothelial dystrophy presents a challenge to the cataract surgeon in predicting how well the compromised cornea will function following cataract surgery. Often the best strategy is to simply perform cataract surgery with proper consent regarding the possibility of subsequent corneal failure. This strategy has become more common as cataract surgery has become gentler and as endothelial keratoplasty has become more elegant. Using dispersive OVD to coat the endothelium and minimizing ultrasound energy can delay or even eliminate the need for subsequent keratoplasty in some cases. It is not clear if FLACS reduces the risk of subsequent endothelial failure because of conflicting studies.[1092, 1093]

A history of blurred vision upon awakening in the morning may indicate endothelial pump impairment. If the lack of tear evaporation while sleeping leads to symptomatic corneal edema, then the likelihood of decompensation after cataract surgery is higher. Patients with Fuchs dystrophy who have a history of morning decline in vision or who have epithelial or stromal edema on slit lamp examination are more likely to progress rapidly after cataract surgery, and surgeons should consider concurrent endothelial transplant surgery.[1094]

Endothelial keratoplasty can create a hyperopic shift that can complicate combined surgery, as described earlier in the Ocular Comorbidities section.

Combined cataract surgery and penetrating keratoplasty

There are several reasons to consider combining cataract extraction with corneal transplantation, even in the presence of a mild cataract:

◆ Cataracts may progress more rapidly after corneal transplantation.

◆ The use of topical corticosteroids following corneal surgery may hasten PSC development.

◆ Cataract surgery after corneal transplantation may damage the corneal graft.

◆ Surgery is limited to a single procedure.

◆ Visual rehabilitation is quicker.

Cataract surgery at the time of penetrating keratoplasty (PK) presents surgical challenges. Intraocular lens power calculation is complicated because the post-penetrating keratoplasty corneal curvature can only be estimated. Since IOL power calculations are less accurate, toric and multifocal IOLs should generally be avoided.[1095] Some surgeons prefer to perform PK first, followed by cataract removal later after sutures are out and the corneal graft has stabilized. If a cataract is removed following suture removal and stabilization of corneal graft keratometry, a more predictable IOL power and, hence, refractive result may be possible.[1096, 1097]

Surgeons should attempt to limit "open-sky" time (the time between corneal trephination and replacement) in whatever approach is taken because of the increased risk of expulsive hemorrhage during hypotony. Performing the PK first and following it with later cataract extraction decreases the open-sky time. These considerations apply to deep anterior lamellar keratoplasty as well. In combined cases, phacoemulsification should be performed before PK if visualization is adequate to limit the amount of open-sky time.[1098] Capsular staining dyes may improve the likelihood of achieving an intact capsulorrhexis when performing cataract extraction through a cloudy cornea.[1099]

Cataract surgery and vitreoretinal procedures

Cataract surgery following intravitreal injections

A history of intravitreal injection can make cataract surgery more complicated. Intravitreal injections are an increasingly common for a variety of conditions including macular degeneration and diabetes.[1100, 1101] Intravitreal injection of corticosteroids can increase the rate of cataract progression.[1102] Iatrogenic capsular damage from intravitreal injections can be difficult to detect preoperatively and may complicate surgery.[1103] Several studies reported a several-fold increase in capsular rupture and retained nuclear material in patients with a history of intravitreal injections.[782, 1005, 1104, 1105] Careful preoperative and intraoperative evaluation of the capsule can sometimes detect capsular damage from intravitreal injections. The surgical approach with known damage to the capsule is similar to other conditions where there is a breach in the posterior capsule (e.g., posterior polar cataract). The surgeon should counsel the patient about the increased risk of complications due to the history of intravitreal injections.

Cataract surgery after pars plana vitrectomy

Cataract surgery is often necessary before, during, or following vitreoretinal surgery. Vitreoretinal procedures may cause pre-existing cataracts to progress, typically manifesting as increased nuclear sclerosis, and a predilection for the development of posterior capsular plaques.[1106-1111] Management of such cataracts may be more complex, because capsular defects or weakened zonular fibers may be present.[782, 1004, 1105] The anterior chamber depth may also be unstable during surgery. Iris hooks can be helpful in these situations. Adequate visual rehabilitation may occur with cataract surgery alone for some retinal pathologies. In silicone oil-filled eyes, bubbles can migrate to the anterior segment and may have to be managed intraoperatively.

Cataract surgery before pars plana vitrectomy

Phacoemulsification may be recommended before a planned vitrectomy to improve visualization of the posterior segment. Secure wound closure is important to permit safe subsequent vitreoretinal maneuvers.[1112-1114] Surgeons should avoid silicone or hydrophilic optic materials when a patient is having a planned vitrectomy following the cataract

surgery. Intraoperative visualization of the posterior segment may become impaired when a silicone optic comes into contact with silicone oil or a gas bubble.[575, 576] Additionally, there have been reports of IOL calcification with the use of intravitreal air, gas, or silicone oil in retinal surgery, often with hydrophilic acrylic IOLs, but other IOL materials can also be similarly affected.[1115]

Combined cataract surgery and vitrectomy

Combined vitreoretinal and cataract surgery offers the advantage of a single operative procedure and anesthesia, potentially faster recovery, and cost-effectiveness.[1116-1118] A wide range of vitreoretinal disorders may be dealt with concomitantly, including vitreous hemorrhage, diabetic retinopathy, epiretinal membrane, macular hole, RD, and posterior vitreous detachment with symptomatic vitreous floaters.[1119-1121] Secure wound closure following the cataract phase of surgery is important to permit safe subsequent vitreoretinal maneuvers.[1112-1114] Possible disadvantages of simultaneous cataract and vitreoretinal surgery include scheduling difficulties, prolonged surgical time, cataract-wound dehiscence caused by globe manipulation during the vitreoretinal portion of surgery, intraoperative miosis after cataract extraction, IOL decentration or optic capture, and undesirable optical effects during vitreoretinal surgery if the IOL is implanted prior to the posterior segment procedure.

Cataract surgery following refractive surgery

Patients who have had corneal refractive surgery present challenges with respect to IOL power calculation. In addition to difficulty measuring the central corneal power accurately, many IOL formulas predict the effective lens position based on the corneal curvature. Keratorefractive steepening or flattening of the cornea therefore introduces a formula artifact. Postoperative power adjustable IOLs may make accurate preoperative power prediction less important. Intraocular lens formulas such as the Kane and the Barrett True K and ASCRS post-refractive surgery IOL power calculator have made IOL selection more accurate.

Cataract surgery following laser refractive procedures

Cataract surgery following refractive surgery is simpler thanks to advances in IOL formulas. Although prior laser refractive surgery, including LASIK and PRK, does not cause anatomic challenges during cataract surgery, IOL power estimation is not as accurate as in normal eyes.[1122]

Following myopic laser vision correction, the cornea tends to have more positive spherical aberration than average and so would benefit from a negative aspheric IOL. Conversely, after hyperopic laser correction, the cornea generally has a negative asphericity and would benefit from a positively aspheric IOL.[1123]

After excimer laser refractive surgery (by either surface or intrastromal photoablation), corneal-power readings with manual keratometers, automated refractors, and topographers are often incorrect as a result of the surgical alteration of the anterior corneal curvature and the changed relationship between anterior and posterior corneal powers. This results in a tendency for hyperopic refractive errors after cataract surgery in eyes with prior myopic photoablation.[1010, 1124-1127] Similarly, eyes that have had prior hyperopic photoablation are prone to myopic optical errors after cataract surgery.[1128]

A number of calculation methods and correction algorithms, some of which require knowledge of prior corneal power, refraction, and the change in manifest refraction, have been developed to help determine IOL power following refractive surgery, but there is presently no consensus about a best method.[1129-1139] Patients should be informed of the potential inaccuracies of IOL power calculation and that further surgery may be necessary to achieve the desired target refraction.

Also, as mentioned in the Intraocular Lens Optical Considerations section, intraoperative aberrometry may aid in IOL selection in laser vision corrected eyes.[328]

Cataract surgery following radial keratotomy

Radial keratotomy (RK) can complicate cataract incision placement. Following RK, it is best to avoid having the new cataract surgical incision cross or intersect pre-existing radial or arcuate incisions, because this could lead to incision dehiscence, wound leak, delayed healing, and irregular astigmatism.[1140-1143] A short scleral incision may lessen the chance of involving the original incisions. The refractive outcome may be quite variable for several weeks or beyond following cataract surgery. Postoperative corneal hydration or edema and elevated IOP may amplify the effect of the RK incisions, causing transient hyperopia and changes in astigmatism. The timing of any further refractive surgical intervention should be delayed until the refraction is stable.[1140]

The ASCRS post-RK IOL power calculator can improve the accuracy of IOL selection. In the case of RK, the induced central corneal flattening renders traditional keratometric readings inaccurate. This is because keratometers estimate the central corneal curvature based on paracentral measurements, and they fail to detect the full degree of central flattening.[1144, 1145] The clinical history method (which requires knowledge of presurgical keratometry and refraction) is generally not helpful following RK due to the common occurrence of progressive central corneal flattening (hyperopic drift) that may continue for years to decades. There are automated computerized systems (topography and tomography) that can help to determine true central corneal power.[1146, 1147]

For the most accurate IOL power calculation for patients who have previously undergone RK or myopic or hyperopic photoablation, the ASCRS developed an online IOL power calculator that is regularly updated and available at http://iolcalc.ascrs.org.[290, 1148]

Cataract surgery and uveitis

There are special issues to consider when patients with uveitis undergo cataract surgery.[1149-1151] Patients with active inflammation, particularly those with anterior or intermediate uveitis, are at substantial risk for complications. A major potential problem, especially among patients with pre-existing iris damage or extensive posterior synechiae, is the development of adhesions between the iris and lens capsule postoperatively. Other potential problems include membrane formation, IOL deposits, zonular problems, and CME. Coordination with the physicians treating the patient's uveitis and any systemic auto-immune disease systemic prior to cataract surgery will provide for appropriate prophylactic anti-inflammatory therapy and improve postsurgical outcomes.

Preoperative management of uveitis

There are many important factors to consider in the presence of uveitis. Ideally, inflammation should be inactive or controlled as much as possible before surgery.[978] Many uveitis specialists advocate 3 months or more of quiescence before surgery, as this reduces the risk of postoperative CME.[957, 978, 979] Even if a patient is on chronic anti-inflammatory therapy, additional topical and/or oral corticosteroids are often recommended before surgery to pre-empt severe postoperative exacerbations.[958] In one study, preoperative treatment with oral corticosteroids seemed to decrease the risk of postoperative CME.[979] The medical regimen should be individualized based on the severity and sequelae of past episodes of uveitis and the ease with which inflammation has been controlled previously. Surgical planning should account for the possible need for other procedures, which are often required because of associated uveitic complications, such as secondary glaucoma. Surgical procedures may need to be modified to manage pre-existing posterior synechiae, pupillary membranes, zonular compromise, and fibrotic scarring of the pupillary margin.

Intraocular lens material in uveitis

The safety of IOLs in most eyes with uveitis is now generally accepted. Intraocular lens material does not seem to have a major influence on the course of postoperative inflammation. A 2014 Cochrane Systematic Review did not represent with certainty the advantage of any IOL material. *(I-, Moderate, Discretionary)* This review did include a study that showed a superior effect of hydrophobic acrylic lenses over silicone lenses,

specifically for posterior synechiae outcomes, but this effect was based on a single study that suffered from potential performance and detection bias.[958] A more recent evidence-based review and meta-analysis indicates that some IOL materials may be associated with better outcomes than others.[957] In this study, eyes receiving acrylic IOLs or heparin-surface-modified (HSM) polymethylmethacrylate IOLs had better visual outcomes than eyes receiving non-HSM polymethylmethacrylate or silicone IOLs.[1152] The authors concluded that preoperative control of uveitis, use of an acrylic or HSM IOL, and a diagnosis of Fuchs heterochromic cyclitis were associated with better outcomes. Lastly, a study of 171 eyes found a good long-term biocompatibility and safety profile in uveitic eyes receiving hydrophobic acrylic IOLs.[1153]

Intraocular lens placement in uveitis

Intraocular lens-related complications may include inflammatory deposits, surface membrane formation, and inflammatory capsular complications capable of causing IOL subluxation. Leaving an eye aphakic may be considered in severely damaged uveitic eyes with extensive pupillary or ciliary membrane formation or signs of intractable inflammation such as hypotony and severe flare. In most cases, placement of an IOL with the optic and haptics in the capsular bag is preferred. However, placement of the entire IOL in the sulcus or prolapse of the optic into the sulcus (haptics in the bag) allows the IOL optic to block the formation of iridocapsular adhesions in high-risk eyes (e.g., extensive iris damage or preoperative posterior synechiae). This technique does not seem to increase postoperative inflammation.[954, 1154] Placement of the haptics in the bag and the optic in the sulcus may prevent posterior synechiae.[1154] With capsular bag placement, a large-diameter capsulorrhexis may also decrease the risk of postoperative synechiae to the anterior capsule. Anterior chamber IOLs may stimulate more inflammation and may be problematic if angle anatomy is compromised. Zonulopathy is common in patients with uveitis and may require supplementary devices such as CTRs for IOL centration. Uveitic zonulopathy can lead to capsular phimosis and late in-the-bag IOL subluxation.[855, 1155] Cleaning off the anterior subcapsular lens epithelial cells (LECs) may be beneficial in preventing capsular phimosis in eyes with uveitis.

Pupil management

Although the pupil may dilate poorly in eyes with uveitis, iris manipulation should be minimized to the extent possible to avoid worsening of inflammation and posterior synechiae formation. Iris prolapse should be avoided during surgery.

Postoperative management

The postoperative use of short-acting topical mydriatic agents may help to prevent postoperative synechiae formation; however, fixed dilation with long-acting cycloplegic agents such as atropine may lead to formation of posterior synechiae in the dilated state. Adjunctive corticosteroids at the time of surgery (IV, periocular, or intraocular) should be considered. Patients with uveitis are at risk of postoperative inflammatory exacerbation. Postoperatively, eyes with uveitis generally require a greater frequency and duration of topical anti-inflammatory treatment and should be monitored closely for complications such as severe iridocyclitis, secondary glaucoma, posterior synechiae, secondary membranes, and CME.[1156]

Postoperative inflammation and CME generally respond to anti-inflammatory treatments. As with preoperative prophylactic treatment, postoperative coordination of management of uveitis patients with a uveitis care provider is recommended.

Cataract in the functionally monocular patient

A functionally monocular patient is one who is primarily dependent on the eye being considered for cataract surgery. There may be significant ocular comorbidity or other high-risk characteristics in such eyes.[1157, 1158] The indications for surgery in the functionally monocular patient are the same as for other patients; that is, when the cataract-impaired vision no longer meets the patient's needs and the anticipated benefits of surgery exceed

the risks. Cataract surgery for these patients results in a greater improvement in functional vision than surgery in binocularly sighted patients.[1159] When the long-term visual outcomes of cataract surgery on the better seeing eye are compared between monocular patients with limited vision in the poorer-seeing eye and no light perception in the poorer-seeing eye, those with limited vision in the poorer-seeing eye fare worse over the long term. The reason is that these eyes are more likely to harbor medical comorbidities such as macular degeneration and diabetic retinopathy, which tend to progress.[1160] Blind eyes are often blind because of trauma or surgical mishap; these issues tend not to affect the better-seeing eye. When cataract surgery is contemplated in a functionally monocular patient, the ophthalmologist has an obligation to inform the patient that bilateral blindness is one of the risks of cataract surgery and that it can result from worsening ocular comorbidity following surgery as well.[1161]

The ophthalmologist and patient should understand that delaying surgery until a cataract is advanced may increase surgical risk and slow visual recovery.

Second-Eye Surgery

Clinical studies provide convincing evidence that binocular summation occurs in individuals who have similar visual acuities in the two eyes and at low illuminance levels.[1162-1167] Patients with a cataract and dissimilar vision in their two eyes (or one eye status post cataract extraction and the second eye with a cataract) demonstrate binocular inhibition.[1167] A large epidemiological study found that persons who exhibit binocular inhibition are more likely to have driving difficulties compared with those who do not.[1162] However, patients with monovision may successfully sacrifice some binocular summation to improve their spectacle independence.

Studies comparing the outcomes of first-eye and second-eye cataract surgeries concluded that patients who had surgery in both eyes had greater improvement in functional status than those who underwent surgery in one eye only.[120, 124, 146, 1168-1173] Patients who had surgery in both eyes were significantly more satisfied with their visual function than patients who had surgery in only one eye.[1168, 1174, 1175] One study demonstrated that the cataractous eye interfered with the visual function of the pseudophakic eye and that complaints of visual disability were eliminated after second-eye surgery.[1176] Another study found that the presence of stereoacuity increased from 32% after first-eye surgery to 90% after second-eye surgery. Binocular horizontal field of vision improved by 20 degrees or more in 54% of patients. The number of patients able to meet the driving standard increased from 52% after first-eye surgery to 86% after second-eye surgery.[1177]

A population-based cohort study of 2849 drivers 60 years old and older in Australia found that both first-eye (61%) and second-eye (23%) cataract surgery were statistically significantly associated in a reduction in crashes compared with the year before first-eye surgery.[1178] Another study showed that drivers 55 and older were significantly less likely to self-regulate their driving practices after first-eye (70% less likely) and second-eye (90% less likely) cataract surgery.[1179] Patients reported spending statistically significantly more time on moderate leisurely physical activity after both first-eye and second-eye surgery.[1178] A study of patients 55 and older who maintained a falls diary documented a 54% ($P = 0.04$) decrease in falls from baseline after first-eye cataract surgery and a 73% ($P = 0.002$) decrease after second-eye cataract surgery.[1180] A study from Vietnam showed similar results.[145] Cataract surgery for both eyes is an appropriate treatment for patients with bilateral cataract-induced visual impairment.[1168, 1170, 1171, 1181]

A review of multiple randomized, controlled studies showed that, in the long term, second-eye cataract surgery is not only clinically effective but has also been found to be cost-effective.[1182] A study in the United Kingdom determined that second-eye surgery was 100% likely to be cost-effective at even relatively low willingness-to-pay thresholds.[1183]

The indications for second-eye surgery are the same as for the first eye. The outcome of surgery on the first eye may affect the timing of second-eye surgery. In some patients, a byproduct of reducing ametropia in the first operated eye may be anisometropia. This may result in impaired stereoacuity and a reduction in a patient's ability to perform daily

activities.[146] A contact lens may make the anisometropia tolerable, but if the imbalance interferes with visual function, second-eye surgery may be appropriate at an earlier stage of cataract development.[1170, 1184]

The appropriate interval between the first-eye surgery and the second-eye surgery is influenced by several factors, including a patient's visual needs and preferences, visual acuity and function of the second eye, the medical and refractive stability of the first eye, and the degree of anisometropia. Before performing second-eye surgery, knowing the refractive error of the first eye can be helpful for refining the IOL power choice for the second eye.[1185-1187]

Immediate Sequential (Same-Day) Bilateral Cataract Surgery

In recent years, centers in Canada, Europe, and other parts of the world have reported excellent safety, efficacy, and economic benefits of immediate sequential bilateral cataract surgery (ISBCS).[1188-1198] The procedure is not commonly performed in the United States[448] because of a fear of bilateral vision loss from complications such as endophthalmitis,[1199] the inability to adjust IOL power selection in the second eye based on the postoperative refractive outcome from the first eye,[1200] and the reduction in Medicare fee-for-service reimbursement for second-eye surgery when performed on the same day.[1201, 1202]

Benefits of ISBCS include fewer perioperative visits and a reduction in associated economic costs to the patient and accompanying driver due to time off from work and travel expenses; increased operating room efficiency; and societal economic savings.[1201, 1203-1206] Prospective comparative trials of ISBCS versus delayed bilateral cataract surgery (DSBCS) document a more rapid improvement of patients' self-reported visual function and similar long-term results.[1192, 1194, 1195] One study found a potential annual cost savings to Medicare of $522 million in 2012 dollars. These potential benefits may become increasingly important in the years ahead, since the projected rate of cataract surgery is expected to grow 72% or more by the year 2036.[1207] An additional potential benefit of ISBCS is a reduction of patient exposure to infection in the health care setting by reducing perioperative visits.[1208] These savings, however, are unlikely to be realized under current facility reimbursement policy, which reduces payment for the second eye when done on the same day. The operating room resources required for bilateral surgery are almost double those for unilateral surgery. Current payments for ISBCS are below costs for most facilities, making them unlikely to schedule ISBCS cases.

Cited drawbacks of ISBCS have included the lack of opportunity to adjust the IOL power in the second eye based on the results in the first eye when there is a refractive surprise.[1199, 1200] This adjustment is based on the assumption that both eyes are optically symmetrical and the type and amount of error in the preoperative measurements or calculations are approximately equivalent in the two eyes.[1187] There is also the potential problem of bilateral dysphotopsia.

However, prospective and retrospective studies show similar results in CDVA, UDVA, and refractive outcomes for immediate and delayed bilateral surgery.[1195, 1196, 1202, 1209] One prospective study showed that 5% of patients in the delayed group had a change of IOL power based on the results of the first eye, but refractive results of second eyes were no different between groups.[1197] As biometric technology and predictive formulas continue to improve, the risk of a refractive surprise and the need for adjusting the second eye appears to be decreasing.[1187, 1210, 1211] Nevertheless, patients at risk for refractive surprise, including a history of post-refractive corneal surgery and very short or long axial lengths, may not be optimal candidates for ISBCS.

The most serious potential complication of ISBCS is bilateral blindness due to endophthalmitis or TASS.[1212, 1213] Sporadic cases of bilateral endophthalmitis following ISBCS have been reported when separation of the two surgical setups was not followed.[1193, 1214-1217] In published reviews, however, bilateral complications are rare and the procedure is considered safe,[1189-1191, 1195, 1209, 1218-1223] with no reports of bilateral endophthalmitis or TASS when recommended guidelines are followed,[1224, 1225] including injection of an intracameral antibiotic.[1194, 1195, 1209, 1222] In a retrospective cohort studying using the American Academy of Ophthalmology IRIS® Registry (Intelligent Research in Sight) database, the rate of

postoperative endophthalmitis following ISBCS versus DSBCS was not statistically significantly different.[1226] Bilateral HORV has been reported, although not following ISBCS.[462] Patients should be screened for ocular comorbidity and those at risk for bilateral adverse events, such as corneal or macular edema, should be considered for exclusion.[1227, 1228]

Immediate sequential bilateral cataract surgery offers a potential benefit for patients who desire same-day surgery. Individual patient preferences and the best interests for the individual patient's visual health and refractive status should be the predominant factors in determining whether same-day bilateral cataract surgery should be performed.[1229] Patient safety considerations should include surgeon comfort with the procedure, attention to cleaning and sterilization practices in the surgery center, use of intracameral medications from different lots, injection of intracameral antibiotic, IOL selection using contemporary biometric technology and formulas, and evaluation and discussion of the potential impact of a patient's ocular comorbidities, if any.[1206, 1228]

Discharge from Surgical Facility

Typical criteria for discharge after ambulatory surgery are as follows:

◆ Vital signs are stable.
◆ The preoperative mental state is restored.
◆ Nausea and vomiting are controlled.
◆ Pain is absent or minimal.
◆ A responsible adult is available to escort the patient home.
◆ Postsurgical care has been reviewed with the patient and/or a responsible family member and written postoperative instructions have been provided, including emergency contact numbers.
◆ A follow-up appointment has been scheduled.

Operative complications of an ocular or medical nature are possible indications for transfer and postoperative hospitalization. In the Study of Medical Testing for Cataract Surgery (n = 19,250 surgeries), there were 61 (0.3%) hospitalizations on the day of cataract surgery.[270] Ocular complications that may require hospitalization include hyphema, uncontrolled elevated IOP, threatened or actual expulsive suprachoroidal hemorrhage, retrobulbar hemorrhage, severe pain, or other ocular problems requiring acute management or careful observation. Medical complications can include cardiac or respiratory instability, a cerebrovascular episode, diabetes mellitus or hypertension requiring acute management, uncontrolled nausea or vomiting, acute urinary retention, and acute psychiatric disorientation requiring management in an acute-care setting with careful monitoring.

Postoperative Management

The operating ophthalmologist has the ultimate responsibility for the preoperative assessment[1230] and postoperative care of the patient, beginning with determining the need for surgery and ending with completing the postoperative care contingent on medical stability of the patient.[1231, 1232] The ophthalmologist who performs the cataract surgery has a unique perspective and thorough understanding of the patient's intraoperative course, postoperative condition, and response to surgery. The postoperative period is the time in which most complications occur and within which stable visual function is achieved. The operating ophthalmologist has an ethical obligation to the patient that continues until postoperative rehabilitation is complete.

The operating ophthalmologist should also provide those aspects of postoperative eye care that are within the unique competence of the ophthalmologist. These do not necessarily include those aspects of postoperative care permitted by law to be performed by auxiliaries. If such follow-up care is not possible, the operating ophthalmologist must make arrangements before surgery to refer the patient to another ophthalmologist for postoperative care with the prior approval of the patient and the ophthalmologist.[1232, 1233] Comanagement is a relationship between an operating ophthalmologist and a nonoperating practitioner for shared responsibility in the postoperative care. Comanagement occurs when the patient consents in writing to multiple providers, the services being performed are

within the providers' respective scopes of practice, and there is written agreement between the providers to share patient care. Transfer of care takes place when there is transfer of responsibility for a patient's care from one qualified health care provider functioning within his or her scope of practice to another who also functions within his or her scope of practice.

The ophthalmologist who performs surgery has an obligation to inform patients about medication instructions, activity restrictions, postoperative eye protection, required visits, signs and symptoms of possible complications, and information for accessing emergency care. The ophthalmologist should also inform patients of their responsibility to follow the advice and instructions provided during the postoperative phase and to notify the ophthalmologist promptly if problems occur. Patients should always have access to an ophthalmologist for appropriate care if serious problems arise.

 (See the Comprehensive Guidelines for the Co-Management of Ophthalmic Postoperative Care for detailed information.[1232])

Postoperative medication regimens vary among practitioners; use of topical antibiotics for infection prophylaxis and of topical corticosteroids and NSAIDs for CME prophylaxis are discussed earlier in this PPP. Topical corticosteroids and NSAIDs are also used for control of postoperative inflammation, but there is insufficient high-level evidence to compare these interventions,[807] *(I+, Moderate, Discretionary)* making it the decision of the operating surgeon to use one or both of these medication classes. Complications of postoperative medications include elevated IOP with corticosteroids and allergic reactions to antibiotics. Significant corneal reactions, including epithelial defects and stromal ulceration and melting, are rare complications of topical ocular NSAID use.[1234-1236]

Postoperative Follow-up

The frequency of postoperative examinations is based on the goal of optimizing the outcome of surgery and swiftly recognizing and managing complications. This requires promptly and accurately diagnosing and treating the complications of surgery, providing satisfactory optical correction, educating and supporting the patient, and reviewing postoperative instructions. Postoperative patients with low-risk surgeries and with no signs or symptoms of possible complications following cataract surgery should be seen within the first 48 hours of surgery. Studies have reported that, for the routine patient, omitting an examination on the day after uncomplicated cataract surgery is associated with a low frequency of serious ocular complications.[1237-1241] Functionally monocular patients and those at high risk of early postoperative complications should be seen within the first 24 hours of surgery.

In the absence of complications, the frequency and timing of subsequent postoperative visits depend largely on the size or configuration of the incision; the need to cut or remove sutures; and when refraction, visual function, and the medical condition of the eye are stabilized. In patients with low-risk, uncomplicated cataract surgery who are seen within 1 day of surgery and remain asymptomatic, a subsequent visit 1 week later rarely serves to change management;[1242] however, this visit may increase medication compliance. More-frequent postoperative visits are generally indicated if unusual findings, symptoms, or complications occur. The patient should have ready access to the ophthalmologist's office to ask questions or seek care.

Components of each postoperative examination should include the following:

◆ Interval history, including use of postoperative medications, new symptoms, and self-assessment of vision
◆ Measurement of visual function (e.g., visual acuity, including pinhole testing or refraction when appropriate)
◆ Measurement of IOP
◆ Slit-lamp biomicroscopy
◆ Counseling/education for the patient or the patient's caretaker
◆ Provision of a management plan

A dilated fundus examination is indicated if there is a reasonable suspicion or higher risk of posterior segment problems. In the absence of symptoms or surgical complications, no study has demonstrated that a dilated fundus examination results in earlier detection of RD. However, dilation is often critical in assessing anterior ocular concerns, such as capsular contracture and IOL malposition and in evaluating retinal issues, such as CME.

When postoperative visual improvement is less than anticipated, the ophthalmologist may perform additional diagnostic testing to evaluate the cause. For example, if maculopathy is suspected, OCT or fluorescein angiography would be appropriate to diagnose cystoid or diffuse macular edema, epiretinal membranes, or AMD. Likewise, corneal topography could help diagnose irregular corneal astigmatism. Automated visual fields may help diagnose a neuro-ophthalmic abnormality. Other testing may be conducted if appropriate.

A final visit should be made to provide an accurate refractive prescription to allow for the patient's optimal visual function. Optical correction can usually be prescribed between 1 and 4 weeks after small-incision cataract surgery[1243] and between 6 and 12 weeks after sutured large-incision cataract extraction surgery.

Posterior Capsular Opacification

Posterior capsular opacification often occurs following cataract surgery by any method and can cause a gradual decrease in visual function.[551, 1244, 1245] The most common cause of PCO is proliferation and metaplasia of LECs that remain in the capsular bag following cataract surgery.[1246, 1247]

The onset of PCO from the time of surgery varies, but it generally increases over time.[1248-1250] The frequency of laser posterior capsulotomy has been reported in the range of less than 5% to 54%.[1251-1253]

The incidence of PCO is influenced by multiple variables. In some eyes, plaques or capsular opacities cannot be removed during surgery for a variety of reasons, or capsular wrinkles develop during the early postoperative period. Studies generally find significantly lower PCO scores for sharp-edged IOLs compared with rounded-edged models.[568, 1254] A 2013 meta-analysis of nine RCTs and several recent longitudinal studies found that hydrophobic sharp-edged IOLs have lower PCO and Nd:YAG laser capsulotomy rates than hydrophilic sharp-edged IOLs.[1255-1258] Additionally, square-edged acrylic, PMMA, and silicone IOLs were found to be comparable in terms of reducing the need for Nd:YAG laser capsulotomy.[1259] *(I+, Strong, Good)* However, one randomized trial indicated that the protective effect of the sharp-edged hydrophobic lens may only be to delay the development of PCO compared with round-edged silicone and PMMA IOLs after 12 years of follow-up.[1260] The incidence of PCO is lower in older patients,[1261] when the anterior capsulorrhexis completely overlaps the entire optic,[1262-1264] and with phacoemulsification (vs. ECCE).[260] No difference in PCO has been found with more prolonged administration of topical corticosteroids or topical NSAIDs.[1012, 1014, 1015]

Polishing the anterior capsule has a variable effect on reducing PCO development.[1265-1267] It probably increases the rate of PCO and accelerates the need for a Nd:YAG laser capsulotomy in most eyes by limiting the ability of the capsule to form a tight bend around the posterior edge of the optic, a bed that would otherwise retard LEC migration posterior to the optic.[1268] Benefits of anterior capsule polishing are improved anterior capsule clarity postoperatively and reduced IOL decentration and capsulorrhexis phimosis.

Posterior laser capsulotomy is an effective surgical procedure to clear the visual pathway to restore visual function and to improve contrast sensitivity.[1269] The indication for performing laser capsulotomy is PCO consistent with an impairment of vision to a level that does not meet the patient's functional needs or critically interferes with visualization of the fundus. The decision to perform capsulotomy should take into consideration the benefits and risks of the laser surgery. Posterior capsulotomy may be indicated earlier in patients with multifocal IOLs because of a greater functional impact of early PCO in low-contrast and glare conditions. Laser posterior capsulotomy should not be performed prophylactically

(i.e., when the capsule remains clear). Same-day bilateral laser capsulotomy is occasionally performed when there are extenuating circumstances such as difficulty traveling. The eye should be inflammation free and the IOL stable prior to performing laser capsulotomy.[1260]

An uncommon condition that is treated with laser posterior capsulotomy is capsular bag distension syndrome, or capsular block syndrome.[1270] This complication is characterized by an accumulation of a milky or clear fluid behind the lens optic associated with anterior displacement of the lens, which may induce decreased vision and produce a myopic refractive shift.[1271, 1272]

Although uncommon, complications of laser capsulotomy include increased IOP,[1273] RD, CME, corneal abrasion, iritis, vitritis, damage to the IOL, persistent floaters, and dislocation of the IOL.[1274] There have been case reports of macular hole formation[1275, 1276] and indolent endophthalmitis[1277] following laser capsulotomy. Having a posterior capsulotomy can also complicate IOL exchange. Axial myopia increases the risk of RD after laser capsulotomy,[1278] as does pre-existing vitreoretinal disease, male gender, young age, vitreous prolapse into the anterior chamber, and spontaneous extension of the capsulotomy.[1279] Two case series reported a 0% to 0.4% incidence of RD 1 to 8 years following laser capsulotomy. In one of these series, there were no RDs in eyes with an axial length less than 24.0 mm.[1280] A recent study of billing records of a large number of patients concluded there was a 0.29% risk of tear and 0.87% risk of RD in the first 5 months following capsulotomy.[1281] Because retinal breaks or detachments are acute events that can occur weeks to possibly years after laser capsulotomy, a routine dilated fundus examination is unlikely to detect retinal pathology that requires treatment in the absence of symptoms. Educating high-risk patients about the symptoms of retinal tears or detachment may facilitate early diagnosis.[1282]

In the absence of risk factors for IOP elevation, routine prophylaxis with ocular hypotensive agents at the time of capsulotomy is not consistently supported by the literature.[1283, 1284] In the presence of risk factors, such as pre-existing glaucoma, a variety of agents to lower IOP have demonstrated efficacy at blunting IOP elevation.[1285-1290] In high-risk patients, the surgeon should monitor the IOP in the early postoperative period. Treatment with topical corticosteroid, NSAID, ocular hypotensive, or cycloplegic agents is dependent on the patient's risk factors and surgeon's preference.

Anterior capsular fibrosis and contracture (capsular contraction syndrome) is caused by metaplastic LECs.[1291] Shrinkage of the anterior capsular opening occurs more frequently in conditions such as pseudoexfoliation syndrome, retinitis pigmentosa, diabetes, uveitis, and eyes with zonular pathology.[1265] Anterior capsule contracture also happens more frequently with silicone than with acrylic optic materials. Anterior capsule polishing may reduce this postoperative phenomenon.[1265, 1266, 1292, 1293] Capsular contracture can lead to decreased visual acuity, IOL tilt or decentration, and IOL dislocation in extreme cases. Treatment of anterior capsular contracture with Nd:YAG or femtosecond laser anterior capsulotomy may be effective.[1265, 1266, 1292]

PROVIDER AND SETTING

It is the unique role of the ophthalmologist who performs cataract surgery to confirm the presence of the cataract, determine the need for surgery, and design and carry out a treatment plan, including postoperative care.[264, 265] Diagnosis and management require medical expertise, surgical skills, and specialized diagnostic and surgical equipment. The ophthalmologist's training, clinical experience, and judgment are necessary to evaluate the medical, ocular, and psychosocial factors used to determine the appropriateness and timing of surgery. Cataract surgery, including use of the femtosecond laser, should be performed only by an appropriately trained ophthalmologist.[1294]

While the performance of certain diagnostic procedures (e.g., measurement of IOP, refraction, biometry) may be delegated to appropriately trained personnel supervised by the ophthalmologist, interpretation of these procedures requires the clinical judgment of the ophthalmologist.

Nearly all cataract surgery is performed in an outpatient setting, which may be in a hospital-based outpatient department or freestanding ambulatory surgery center. In-office surgery is being considered by Medicare at the time of this PPP. A Cochrane Systematic Review has concluded that there is no

difference in outcome or increased risk of postoperative complications between outpatient and inpatient cataract surgery.[1295] *(I+, Good, Strong)*

The surgical facility should comply with local, state, and federal regulations and standards governing the particular setting of care. Inpatient surgery may be necessary if there is a need for complex anesthetic or surgical care, multiple procedures, or postoperative care requiring an acute-care setting.

COUNSELING AND REFERRAL

The patient should be informed preoperatively about the possibility of visual impairment continuing after cataract surgery and the potential for rehabilitation in such cases.[1296] More information on vision rehabilitation, including materials for patients, is available at www.aao.org/smart-sight-low-vision.

Appropriate referral to a specialist should be considered when the postoperative course does not proceed as expected or does not respond to standard therapy. Examples include persistent inflammation, nonresolving CME, or uncontrolled glaucoma.

SOCIOECONOMIC CONSIDERATIONS

Utilization of Cataract Surgery in the United States

In 2017, a total of 3.38 million cataract procedures were performed on Medicare beneficiaries who were not enrolled in Medicare advantage plans (managed care plans for Medicare patients). This suggests that 5.2 million cataract surgeries were performed in 2017, if Medicare advantage plans are also considered and if the rate in these plans is the same as for Medicare patients.[1297] The projected rate of cataract surgery is expected to grow 72% or more by the year 2036, and this may be an underestimate.[1207]

When assessed across populations residing in different states or metropolitan areas, there is wide and largely unexplained variation in the rate of cataract surgery, from 7.5% to 37.3%.[1298] In one study, factors associated with a higher rate of cataract surgery were female gender, living in a more southerly latitude, a higher concentration of optometrists in a specific geographic area, and a higher allowed charge for cataract surgery.[1299] A higher concentration of ophthalmologists was not associated with a higher rate of cataract surgery. The average age of patients undergoing cataract surgery is widely variable from 60 to 80 years old, with great variation in different areas of the country.[1298]

The utilization of cataract surgery in the United States has been found to be appropriate in the vast majority of studies. A study at 10 academic medical centers found that 2% of cataract surgeries performed were classified as inappropriate based on available records.[1300] An inappropriate rating meant that the risks of surgery were deemed to exceed the potential benefits as rated by a physician review panel. The percentage deemed inappropriate in this study is consistent with earlier estimates of 2.5% by the 1993 U.S. General Accounting Office and a rate of 1.7% by the U.S. Inspector General.[1300] Cataract surgery inappropriateness ratings are comparable to the rate found for coronary artery bypass graft surgery (2.4% inappropriate) and lower than the rate for carotid endarterectomies (10.6% inappropriate).[1301, 1302] The criteria for appropriateness of cataract surgery were based on indicators of visual acuity and functional impairment, such as difficulty driving, reading, and other activities of daily living. The study did note that the recorded information varied, particularly on functional impairment, and increased attention to documenting specific functional impairments would be appropriate. A study of Medicare beneficiaries in 13 large areas in the United States found that cataract surgery ranked among procedures with the least variation in use.[1303] Also, second-opinion programs implemented for cataract surgery have not lowered surgical rates, because the initial recommendations for surgery were found to be appropriate.

The validity of the appropriateness methodology used to evaluate the utilization of cataract surgery was supported by a study of the association between the appropriateness rating and postoperative visual acuity.[1304] More recent studies have added a patient-reported visual function questionnaire.[1305] For a sample of 768 patients, 89% of those who had surgeries rated as appropriate were found to have a visual acuity improvement of at least 2 lines postoperatively. For the group that had surgeries rated as inappropriate, 36% had a visual acuity improvement of at least 2 lines postoperatively. This finding suggests that the functional benefit of cataract

surgery can be unpredictable in some individuals and cannot always be accurately predicted preoperatively.

Cost and Cost-Effectiveness of Cataract Surgery in the United States

In 2010, the national average surgeon reimbursement for cataract surgery/IOL implantation was $713.86. In 2020, it dropped to $557, a 22% decrease.[1306] The total cost for cataract surgery/IOL implantation for a Medicare beneficiary in the ambulatory surgery center setting was about $2335 in 2010. This includes the initial office evaluation as well as refraction, biometry, surgical facility fee, surgeon and anesthesia professional fees, and medications.

Cataract surgery with IOL implantation was the most frequently performed operation and the single largest expenditure for any Part B procedure in the Medicare program, calculated by Part B procedure codes based on allowed charges.

Methods to evaluate whether the cost of a medical intervention is an effective use of available resources include cost-effectiveness or cost-utility calculations. The quality-adjusted life year (QALY) is a measure of a disease burden, including both the quality and the quantity of life lived. It is used in assessing the monetary value of a medical intervention. The QALY is based on the number of years of life that would be added by the intervention. Each year in perfect health is assigned the value of 1.0 down to a value of 0.0 for death. If the extra years would not be lived in full health, for example, if the patient would be blind, lose a limb, or have to use a wheelchair, then the extra life-years are given a value between 0 and 1 to account for this. The QALY is used in cost-utility analysis to calculate the ratio of cost to QALY improvement and compare the value of interventions of different health conditions. Lower cost per QALY represents a more cost-effective medical intervention.

The 2017 hypothetical cost per QALY gained for cataract surgery in one eye was estimated at US $1,001 in the United States, depending on the study and including direct costs only,[1307] which is 41.8% more cost-effective than in 2012 and 73.1% more cost-effective than in the year 2000. The patient value gained from cataract surgery is in the top 5% of 700 health care interventions that have been evaluated by cost-utility analysis.[1297] The cost per QALY calculation for cataract surgery compares favorably with other medical treatments. Single-vessel coronary artery bare-metal stent for coronary artery disease costs $13,972/QALY, beta blocker treatment of arterial hypertension costs $3,640/QALY, total knee arthroplasty costs $15,292/QALY, and normoglycemic management of non-insulin dependent diabetes mellitus costs $25,560/QALY. Cataract surgery is far more cost-effective than these important medical treatments.

Medical technology is valuable if the benefits of medical advances exceed the costs. One study analyzed technological advances in treatment of five conditions, including cataracts.[1308] In four of the conditions—heart attacks, low-birthweight infants, depression, and cataracts—the estimated benefit of technological changes is much greater than the cost. The medical advances in cataract surgery from the late 1960s to present have resulted in increased safety and improved outcomes. Additionally, the cost-effectiveness of new-technology IOLs, such as toric IOLs, was superior to the lifetime cost of eyeglasses.[1309] One estimate of the present benefit value of cataract surgery is $370,018, which is far greater than the average cost of treatment at $2,526. This accounts for direct costs of cataract surgery and the costs of impaired vision without cataract surgery over a 14-year period. [1297]

Cataract surgery is the most cost-effective procedure performed in medicine today.[1310-1312] Immediate sequential bilateral cataract surgery may be more cost-effective in some payer settings than delayed sequential bilateral cataract surgery.[1313] The cost-effectiveness of cataract surgery compares favorably with other fall prevention strategies such as strength and balance exercise programs and home safety evaluations.[1314]

The common use of intraoperative and postoperative prescription drops also adds to the patient's financial burden. In 2016, the mean cost of postoperative drops was $228 for one cataract surgery, and $324 for two. Brand name prescriptions accounted for over 57% of the prescriptions. Generic medications could save patients 70%.[1315]

New technology in cataract surgery, including the use of advanced technology IOLs and femtosecond lasers, represent an increased out-of-pocket expense for cataract patients. Currently, these technologies are used in a small portion of total cases, but their use is expected to increase over the coming years. Although some benefits of new technology are clear, others remain ambiguous. Their use does add to the patient's economic health care burden.[1316]

Merit-based Incentive Payment System

The Merit-Based Incentive Payment System (MIPS) is a replacement and expansion of the Physician Quality Reporting System program that was initially launched by the Centers for Medicare and Medicaid Services in July 2007. The purpose is to encourage quality improvement and cost reduction using clinical performance measures on a variety of clinical conditions. Physicians are rewarded or penalized via Medicare reimbursement for reporting on quality measures and practice improvement performance. The latest information on the Physician Quality Reporting System is available at www.aao.org/medicare/quality-reporting.

APPENDIX 1. QUALITY OF OPHTHALMIC CARE CORE CRITERIA

*Providing quality care
is the physician's foremost ethical obligation, and is
the basis of public trust in physicians.
AMA Board of Trustees, 1986*

Quality ophthalmic care is provided in a manner and with the skill that is consistent with the best interests of the patient. The discussion that follows characterizes the core elements of such care.

The ophthalmologist is first and foremost a physician. As such, the ophthalmologist demonstrates compassion and concern for the individual, and utilizes the science and art of medicine to help alleviate patient fear and suffering. The ophthalmologist strives to develop and maintain clinical skills at the highest feasible level, consistent with the needs of patients, through training and continuing education. The ophthalmologist evaluates those skills and medical knowledge in relation to the needs of the patient and responds accordingly. The ophthalmologist also ensures that needy patients receive necessary care directly or through referral to appropriate persons and facilities that will provide such care, and he or she supports activities that promote health and prevent disease and disability.

The ophthalmologist recognizes that disease places patients in a disadvantaged, dependent state. The ophthalmologist respects the dignity and integrity of his or her patients and does not exploit their vulnerability.

Quality ophthalmic care has the following optimal attributes, among others.

◆ The essence of quality care is a meaningful partnership relationship between patient and physician. The ophthalmologist strives to communicate effectively with his or her patients, listening carefully to their needs and concerns. In turn, the ophthalmologist educates his or her patients about the nature and prognosis of their condition and about proper and appropriate therapeutic modalities. This is to ensure their meaningful participation (appropriate to their unique physical, intellectual and emotional state) in decisions affecting their management and care, to improve their motivation and compliance with the agreed plan of treatment, and to help alleviate their fears and concerns.

◆ The ophthalmologist uses his or her best judgment in choosing and timing appropriate diagnostic and therapeutic modalities as well as the frequency of evaluation and follow-up, with due regard to the urgency and nature of the patient's condition and unique needs and desires.

◆ The ophthalmologist carries out only those procedures for which he or she is adequately trained, experienced and competent, or, when necessary, is assisted by someone who is, depending on the urgency of the problem and availability and accessibility of alternative providers.

◆ Patients are assured access to, and continuity of, needed and appropriate ophthalmic care, which can be described as follows.

  ◦ The ophthalmologist treats patients with due regard to timeliness, appropriateness, and his or her own ability to provide such care.

  ◦ The operating ophthalmologist makes adequate provision for appropriate pre- and postoperative patient care.

  ◦ When the ophthalmologist is unavailable for his or her patient, he or she provides appropriate alternate ophthalmic care, with adequate mechanisms for informing patients of the existence of such care and procedures for obtaining it.

  ◦ The ophthalmologist refers patients to other ophthalmologists and eye care providers based on the timeliness and appropriateness of such referral, the patient's needs, the competence and qualifications of the person to whom the referral is made, and access and availability.

  ◦ The ophthalmologist seeks appropriate consultation with due regard to the nature of the ocular or other medical or surgical problem. Consultants are suggested for their skill, competence, and accessibility.

> They receive as complete and accurate an accounting of the problem as necessary to provide efficient and effective advice or intervention, and in turn respond in an adequate and timely manner.
>
> - The ophthalmologist maintains complete and accurate medical records.
> - On appropriate request, the ophthalmologist provides a full and accurate rendering of the patient's records in his or her possession.
> - The ophthalmologist reviews the results of consultations and laboratory tests in a timely and effective manner and takes appropriate actions.
> - The ophthalmologist and those who assist in providing care identify themselves and their profession.
> - For patients whose conditions fail to respond to treatment and for whom further treatment is unavailable, the ophthalmologist provides proper professional support, counseling, rehabilitative and social services, and referral as appropriate and accessible.

- Prior to therapeutic or invasive diagnostic procedures, the ophthalmologist becomes appropriately conversant with the patient's condition by collecting pertinent historical information and performing relevant preoperative examinations. Additionally, he or she enables the patient to reach a fully informed decision by providing an accurate and truthful explanation of the diagnosis; the nature, purpose, risks, benefits, and probability of success of the proposed treatment and of alternative treatment; and the risks and benefits of no treatment.

- The ophthalmologist adopts new technology (e.g., drugs, devices, surgical techniques) in judicious fashion, appropriate to the cost and potential benefit relative to existing alternatives and to its demonstrated safety and efficacy.

- The ophthalmologist enhances the quality of care he or she provides by periodically reviewing and assessing his or her personal performance in relation to established standards, and by revising or altering his or her practices and techniques appropriately.

- The ophthalmologist improves ophthalmic care by communicating to colleagues, through appropriate professional channels, knowledge gained through clinical research and practice. This includes alerting colleagues of instances of unusual or unexpected rates of complications and problems related to new drugs, devices or procedures.

- The ophthalmologist provides care in suitably staffed and equipped facilities adequate to deal with potential ocular and systemic complications requiring immediate attention.

- The ophthalmologist also provides ophthalmic care in a manner that is cost effective without unacceptably compromising accepted standards of quality.

APPENDIX 2. INTERNATIONAL STATISTICAL CLASSIFICATION OF DISEASES AND RELATED HEALTH PROBLEMS (ICD) CODES

Cataract, which includes entities with the following ICD-10 classifications:

	ICD-10 CM
Cortical ARC	H25.01–
Anterior subcapsular polar ARC	H25.03–
Posterior subcapsular polar ARC	H25.04–
Other age-related incipient cataract, right eye (coronary; punctate ARC, water clefts)	H25.09–
Age-related nuclear cataract	H25.1–
ARC, morgagnian type, (hypermature cataract)	H25.2–
Combined forms of ARC	H25.81–
Total or mature cataract	H25.89 Other ARC
ARC; exfoliation of lens capsule	H25.89 Other ARC

ARC = age-related cataract; ICD = International Classification of Diseases; CM = Clinical Modification used in the United States; (–) = 1, right eye; 2, left eye; 3, bilateral.

Additional information:
- For bilateral sites, the final character of the codes indicates laterality. If no bilateral code is provided and the condition is bilateral, separate codes for both the left and right side should be assigned. Unspecified codes should be used only when there is no other code option available.
- When the diagnosis code specifies laterality, regardless of which digit it is found in (i.e., 4th digit, 5th digit, or 6th digit):
  - Right is always 1
  - Left is always 2
  - Bilateral is always 3

APPENDIX 3. NUTRITION AND CATARACTS

Most randomized controlled studies of nutritional supplements have not demonstrated a beneficial effect of high-dose supplements on cataract development or progression (Table A3-1). Observational studies of nutrition and cataract with more than 10,000 participants (Table A3-2) have reported either no association[1317] or a reduced risk of cataract.[211, 217-219, 1318-1321 1317]

TABLE A3-1   SUMMARY OF RANDOMIZED CONTROLLED TRIALS OF NUTRITIONAL SUPPLEMENTS AND CATARACTS

Study	Date Published	Sample Size	Results
Beta Carotene			
Alpha-tocopherol, beta-carotene study[1322]	1998	28,934 men	No effect of beta-carotene on risk for cataract surgery
Physicians' Health Study[1323]	2003	22,071	No effect of treatment on cataract development
			For current smokers at baseline, supplementation appeared to lessen their excess risk by about one-quarter
Women's Health Study[1324]	2004	36,735 women	No effect of treatment on cataract development
Lutein/Zeaxanthin			
Age-Related Eye Disease Study 2 (AREDS2)[1325]	2013	3159	No effect on rate of cataract surgery, development of posterior subcapsular or cortical cataracts, or vision loss
Multivitamin/Mineral			
Linxian Cataract[1326]	1993	2141	36% reduction in development of nuclear cataracts in a nutritionally deficient population
Nutritional Supplements and Age-Related Cataract[212]	2008	1020	34% reduction in nuclear cataract; twofold increased risk of posterior subcapsular cataract
Physicians' Health Study II[213]	2014	11,497 men	Long-term multivitamin use moderately decreased the risk (9% lower) of nuclear cataract
Omega-3 Long-Chain Polyunsaturated Fatty Acids (LCPUFAs)			
Age-Related Eye Disease Study 2 (AREDS2)[1325, 1327]	2013	3159	No effect on cataract progression
Riboflavin/Niacin			
Linxian Cataract[1326]	1993	3249	44% reduction in development of nuclear cataracts in a nutritionally deficient population
Selenium			
Selenium and Vitamin E Cancer Prevention Trial (SELECT) Eye Endpoints Study[1328]	2015	11,267 men	No effect of selenium on development of cataract
Vitamin C and E			
Physicians' Health Study II[1329]	2010	11,545 men	No effect on cataract development of C alone, E alone, or C and E

TABLE A3-1 SUMMARY OF RANDOMIZED CONTROLLED TRIALS OF NUTRITIONAL SUPPLEMENTS AND CATARACTS (CONTINUED)

Study	Date Published	Sample Size	Results
Vitamin C, E, and Beta-Carotene			
Age-Related Eye Disease Study[1330]	2001	4629	No effect of treatment on the development or progression of cataracts
Antioxidants in Prevention of Cataracts Study[1331]	2006	798	No effect of treatment on progression of cataracts
Roche European American Cataract Trial[1332]	2002	297	No effect of treatment on the progression of cataracts in the U.K. group; small positive treatment effect in U.S. participants
Vitamin E			
Alpha-tocopherol, beta-carotene study[1322]	1998	28,934	No effect of vitamin E on risk for cataract surgery
SELECT Eye Endpoints Study[1328]	2015	11,267 men	No effect of vitamin E on development of cataract
Vitamin E, Cataract and Age-Related Maculopathy Trial[1333]	2004	1193	No effect of treatment on the development or progression of cataracts
Women's Health Study[1334]	2008	37,675 women	No effect of vitamin E on development of cataract (600 IU QOD)
Vitamin E and Beta-Carotene			
Alpha-tocopherol, beta-carotene Cancer Prevention Study[1335]	1997	1828	No effect of treatment on the development or progression of cataracts

TABLE A3-2 SUMMARY OF OBSERVATIONAL STUDIES OF NUTRITION AND CATARACTS (n>10,000)

Study	Date Published	Type of Study	Sample Size	Measure	Results
Dietary Antioxidants					
Swedish Mammography Cohort[220]	2014	Prospective cohort	30,607 women	Dietary intake	Antioxidants in diet (primarily fruits and vegetables, whole grains, coffee): 12.8% lower risk for cataract extraction in highest quintile of antioxidant intake compared with those in lowest quintile
Dietary Intake					
European Prospective Investigation into Cancer and Nutrition[219]	2011	Prospective cohort	27,670	Dietary intake	Progressive decrease in risk of cataract in high meat eaters to low meat eaters, fish eaters (participants who ate fish but not meat), vegetarians, and vegans
Vegetarianism					
Oxford arm of European Prospective Investigation into Cancer and Nutrition (EPIC-Oxford)[219]	2011	Prospective cohort	27,670	Dietary intake	Vegetarians at lower risk of cataracts than meat eaters
Fat Intake					
Nurses' Health Study[218]	2005	Prospective cohort	71,083 women	Dietary intake	Reduced risk of cataract extraction with higher intake of long-chain fatty acids and fish

TABLE A3-2 SUMMARY OF OBSERVATIONAL STUDIES OF NUTRITION AND CATARACTS (n>10,000) (CONTINUED)

Study	Date Published	Type of Study	Sample Size	Measure	Results
Fruit and Vegetable Intake					
Women's Health Study[217]	2005	Prospective cohort	35,724 women	Dietary intake	Reduced risk of cataracts associated with higher intakes of fruits and vegetables
Lutein/Zeaxanthin					
Health Professionals Follow-up Study[1336]	1999	Prospective cohort	36,644 men	Dietary intake	Modestly lower risk of cataract extraction in men with higher dietary intake of lutein/zeaxanthin
Multivitamin Supplement					
Nurses' Health Study[1317]	1992	Prospective cohort	50,828 women	Supplement use	No association with multivitamin use and cataract extraction
Nurses' Health Study[1337]	1999	Prospective cohort	73,956 women	Supplement use	Little overall benefit for risk of cataract extraction in those taking for ≥10 years
Physicians' Health Study[1318]	1994	Prospective cohort	17,744 men	Supplement use	Reduced risk of cataracts
Cohort of Swedish men[1338]	2013	Prospective cohort	31,120 men	Supplement use	Not associated with cataract risk
Riboflavin/Niacin					
Nurses' Health Study[1317]	1992	Prospective cohort	50,828 women	Total dietary intake	No association
Vitamin C					
Nurses' Health Study[1337]	1999	Prospective cohort	73,956 women	Supplement use	No significant association with risk for cataract extraction, used continuously for ≥10 years
Japan Public Health Center-Based Prospective Study[1320]	2007	Prospective cohort	35,186	Total dietary intake	Reduced incidence of cataract diagnosis or extraction with higher vitamin C intake
Swedish Mammography Cohort[1339]	2010	Prospective cohort	24,593 women	Supplement use	25% increased risk for cataract extraction for vitamin C supplement users
Cohort of Swedish men[1338]	2013	Prospective cohort	31,120 men	Supplement use	21% increased risk of cataract
Twins U.K. Cohort[1231]	2016	Prospective cohort	2054 white female twins	Total dietary intake	Reduced risk of cataracts associated with vitamin C intake over 10 years
Vitamin E					
Nurses' Health Study[1317]	1992	Prospective cohort	50,828 women	Total dietary intake and supplement	No association
Cohort of Swedish men[1338]	2013	Prospective cohort	31,120 men	Supplement use	59% increased risk of cataract

AREDS2 = Age-Related Eye Disease Study 2.

APPENDIX 4. WRONG-SITE WRONG-IOL SURGERY CHECKLIST

Wrong-site-wrong-IOL checklist

What follows is one example of how to document in the surgery chart that all the appropriate steps have been taken in preventing wrong-site and wrong-surgery. Surgeons and administration may wish to include something similar in their charts to ensure that steps are being followed appropriately for every patient. Individuals who perform each task check off the appropriate box, and the surgeon and nurse sign the bottom.

Pre-operative Area

- The informed consent form describes the procedure and operative eye. Abbreviations are not acceptable.
- Prior to administration of eye drops, the nurse asks the patient which eye is to be operated on. The patient's operative eye is appropriately marked in the pre-operative holding area.
- The pre-operative nursing staff ensures the patient's response, informed consent, and doctor's orders for dilation all match for the operative eye.
- The surgeon discusses with the patient the appropriate procedure and ensures that the appropriate eye is marked.

Operating Room

- The office chart notes are available in the operating room.
- Prior to draping, a time out is performed verifying:
  – Patient's name
  – Patient's birth date
  – Procedure
  – Operative eye
  – Lens implant style
  – Lens implant power
- Prior to draping, circulating nurse ensures that operative plan is visible so that the surgeon can read it while gowned and gloved.
- The circulating nurse writes the patient's name, operative eye, IOL style, and IOL power on the white board.

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The Eye M.D. Association

This checklist may be downloaded from the Patient Safety Statement, Recommendations of American Academy of Ophthalmology Wrong-site Task Force (revised 2014), available at www.aao.org/patient-safety-statement/recommendations-of-american-academy-ophthalmology-.

APPENDIX 5. LITERATURE SEARCHES FOR THIS PPP

Literature searches of the PubMed and Cochrane databases were conducted in July 2021; the search strategies were as follows.

Refractive cataract surgery:
("refractive cataract surgery"[tiab]) OR (((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab] OR Lens implantation, intraocular[mh] OR cataract[tiab]) AND (refractive[tiab] OR "power calculation" OR toric[tiab] OR multifocal[tiab] OR presbyopic[tiab] OR multifocality[tiab])))

Intraoperative refractive guidance:
((((((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab]))))) AND (((((((((((("image guidance") OR (("image guidance system" OR "image guidance systems"))) OR "intraoperative aberrometry") OR (intraoperative[tiab] AND aberrometry[tiab])) OR "fluoroscopic guidance"[tiab]) OR (fluoroscopic[tiab] AND guidance[tiab])) OR (("intracameral illumination" OR "intracameral illuminations"))) OR "intraoperative oct") OR "intraoperative optical coherence tomography") OR "monitoring, intraoperative"[mh]) OR "tomography, optical coherence/methods"[mh]) OR "microscopy"[tiab]) OR "monitoring, intraoperative/instrumentation"[mh]) OR "optical imaging/methods"[mh]))) OR (("intraoperative refractive monitoring") OR (intraoperative[tiab] AND refractive[tiab] AND guidance[tiab]))

Alternative technologies for nucleus disassembly: ((((((nucleus[tiab]) AND (removal[tiab] OR disassembly[tiab] OR dropped[tiab] OR division[tiab])) AND ("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab] OR cataract[tiab]))) OR ((((("flacs"[tiab] OR "femtosecond laser assisted surgery"[tiab] OR "miloop" OR "microfilament" OR "small incision cataract surgery"[tiab] OR sics[tiab])) AND ("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab] OR cataract[tiab]))) AND nucleus[tiab])) OR ((("nucleus disassembly") OR "nucleus removal"))
Alternative to drops for postoperative drug delivery: (((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab]))) AND (postoperative[tiab] OR postop[tiab])) AND ((("drug delivery"[tiab] OR drug[tiab] OR drugs[tiab] OR antibiotic[tiab] OR antibiotics[tiab]) AND (intracameral[tiab] OR "sub tenons"[tiab] OR subtenon[tiab] OR "intracanalicular"[tiab] OR "reservoir devices"[tiab] OR dropless[tiab] OR nondropless[tiab] OR alternative[tiab] OR dual[tiab] OR drug delivery systems[mh] OR "glucocorticoids/administration and dosage"[mh] OR "injections, intraocular"[mh] OR "postoperative complications/prevention and control"[mh] OR "drug delivery systems/methods"[mh] OR "sustained-release"[tiab] OR drop-free[tiab] OR topical[tiab] OR subconjunctival[tiab] OR "slow-release"[tiab] OR irrigative[tiab]))
Surgical care delivery settings: ((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab]))) AND ("office-based"[tiab] OR "office"[tiab] OR "hopd"[tiab] OR "hospital outpatient department"[tiab] OR "asc"[tiab] OR "ambulatory surgery center"[tiab] OR outpatient[tiab] OR hospital[tiab] OR ambulatory[tiab] OR "emergency department"[tiab] OR outpatients[mh] OR ambulatory[mh] OR "ambulatory care facilities"[mh] OR ambulatory care facilities/trends[mh])

Timing of second eye surgery: ((((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab]))) AND ((((("second eye" AND surg*))) OR "same day"[tiab]) OR "second eye"[tiab]))) OR ((("second eye surgery" AND cataract)) OR (("second eye cataract" OR "second eye cataract extraction" OR "second eye cataract patients" OR "second eye cataract surgeries" OR "second eye cataract surgery")))
Legal Risks: ((((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab]))) OR ((((((("retinal detachment"[tiab] OR "capsule tear"[tiab] OR "dropped nucleus"[tiab] OR perforation[tiab] OR perforated[tiab]))) OR ((wrong[tiab] AND (lens OR "intraocular lens"[tiab]))))) OR (((lens[tiab] OR iol[tiab])) AND (removal[tiab] OR exchange[tiab])))) AND cataract))) AND (((legal[tiab] OR law[tiab] OR lawsuit[tiab] OR problem* OR Liability, legal[mh] OR malpractice[mh] OR medical errors[mh] OR cataract extraction/legislation and jurisprudence[mh] OR diagnostic errors[mh] OR medicolegal[tiab])) OR (litigation[tiab] OR litigations[tiab] OR malpractice[tiab] OR medicolegal[tiab] OR misdiagnosis[tiab]))
General: "cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab]

Diagnosis: "cataract"[tiab] AND (diagnosis[majr] OR diagnose[tiab] OR diagnosis[tiab] OR detect[tiab])

Therapy: "cataract extraction"/therapy[mh]

Lens Implantation: "lens implantation, intraocular"[mh] OR lens implantation[tiab]

Endophthalmitis: (endophthalmitis[mh] OR endophthalmitis[tiab]) AND ("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab] OR cataract[tiab])

Corneal Transplantation/Penetrating Keratoplasty: ("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab] OR cataract[tiab]) AND (Keratoplasty, Penetrating [mh] OR "corneal transplantation"[mh] OR "Endothelial Keratoplasty" OR DSAEK OR DSEK OR DMEK OR DLEK OR "posterior lamellar keratoplasty")

Risk Factors: (((("cataract/etiology"[mh] OR "cataract/epidemiology"[mh] OR "cataract/ethnology"[mh]) AND "risk factors"[mh])) OR ((("cataract/prevention and control"[majr]) OR ("cataract/epidemiology"[mh])) AND "prevalence"[mh]

Rate – Appropriateness: ((((cataract extraction[mh] AND "statistics and numerical data"[MeSH Subheading])) AND appropriate*[tiab])) OR ((cataract extraction[MeSH Terms] AND appropriateness))

Visual Function and Quality of Life: ((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab])))) AND (("Quality of Life"[mh] OR "qol"[tiab] OR "Activities of Daily Living"[mh] OR "Disability Evaluation"[mh] OR "Automobile Driving"[mh] OR depression[mh] OR anxiety[mh] OR "stress, Psychological"[mh] OR "accidental falls"[mh]))

Evaluation of Visual Impairment: ((("cataract/diagnosis"[MeSH Terms]) AND ("visual acuity"[mh] OR "contrast sensitivity"[mh] OR "vision tests"[mh] OR Questionnaires[mh]))) OR ((cataract[mh]) AND ((Questionnaires[tiab] OR "sickness impact profile"[mh])))

Supplemental Ophthalmic Testing: ((("cataract"[MeSH Terms]) AND ("ultrasonography"[MeSH Terms] OR ultrasonography[tiab]))) OR ((((cataract[mh]) OR ("cataract extraction"[mh]))) AND (("potential vision"[tiab] OR "ocular wavefront"[tiab] OR "corneal topography"[tiab] OR "potential acuity"[tiab] OR "near card"[tiab] OR glare disab*[tiab] OR glare test*[tiab])OR "scanning laser"[tiab] OR "laser interferometer"[tiab] OR "fluorescein angiography"[mh] OR "Tomography, Optical Coherence"[MAJR] OR "corneal pachymetry"[tiab] OR specular microscop*[tiab] OR "evoked potential"[tiab])))

Nonsurgical Management: ((("cataract/chemically induced"[MeSH Terms]) AND ((corticosteroid*[tiab] OR steroid*[tiab] OR glucocorticoid*[tiab] OR glucosteroid*[tiab])))) OR ((cataract[mh]) AND (smoking[mh] OR "dietary supplements"[mh] OR vitamins[mh] OR antioxidants[mh]))

Preoperative Medical Evaluation: (("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab] OR cataract[mh])) AND ("diagnostic tests, routine"[mh] OR "preop"[tiab] OR preoperative[tiab] OR "diagnostic test"[tiab] OR "diagnostic evaluation"[tiab])

Anesthesia: ((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab]))) AND ((Anesthesia[mh] OR aenesth*[tiab] OR anesthet*[tiab]))

TASS (Toxic anterior segment syndrome): ("tass"[tiab]) OR ("toxic anterior segment syndrome" OR "toxic anterior segment syndrome tass" OR TASS[tiab])

TPSS (Toxic posterior segment syndrome): ((("toxic posterior segment syndrome") OR (toxic[tiab] AND posterior[tiab] AND segment[tiab] AND syndrome[tiab]))) OR (("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab]) AND TPSS)

HORV (Hemorrhagic Occlusive Retinal Vasculitis): (((((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab] OR cataract[tiab]))) AND horv)) OR "hemorrhagic occlusive retinal vasculitis"

Surgical Techniques: (((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab])))) AND (((((("incision"[tiab]) OR "microincision"[tiab]) OR "femtosecond"[tiab]) OR "minimally invasive surgical procedures"[mh]) OR "phaco"[tiab]) OR "phacoemulsification"[tiab]) OR "femtosecond laser")

Outcomes: ("cataract extraction"[MeSH Terms]) AND ("visual acuity"[majr] OR "treatment outcome"[majr] OR "outcome assessment, health care"[majr])

Complications of Surgery & Complications of IOLs: (((((((("cataract extraction"[majr]) AND (("postoperative complications"[majr]) OR "intraoperative complications"[majr]))) OR "cataract extraction/adverse effects"[MeSH Major Topic]) OR (("lenses, intraocular/adverse effects"[majr]) AND (cataract[tiab] OR cataracts[tiab]))) OR (("lenses, intraocular"[MAJR]) AND ("Postoperative Complications"[MAJR]) AND (cataract[tw] OR cataracts[tw]))) OR (("lenses, intraocular"[MAJR]) AND ("Intraoperative Complications"[MAJR]) AND (cataract[tw] OR cataracts[tw]))) OR "lens implantation, intraocular/adverse effects"[MeSH Terms]) OR ("lens capsule, crystalline/injuries"[MeSH Terms] AND (cataract[tw] OR cataracts[tw]))

Ocular Comorbidities: ((((((((((((((((("uveitis"[mh] OR uveitis[tiab])) OR ("diabetic retinopathy"[mh] OR "diabetic retinopathy"[tiab])) OR ("macular degeneration"[mh] OR "macular degeneration"[tiab])) OR ("amblyopia"[mh] OR amblyopia[tiab])) OR (glaucoma[mh] OR glaucoma[tiab])) OR ("exfoliation Syndrome"[mh] OR "exfoliation syndrome"[tiab] OR "retinopathy of prematurity"[mh] OR "retinopathy of prematurity"[tiab])) OR (fuchs*[tiab] AND dystrophy[tiab])) OR ("cloudy cornea"[tiab] OR "cloudy corneas"[tiab] OR (cloud*[tiab] AND cornea*[tiab]))) OR ((miotic[tiab] OR miosis[tiab]) AND pupil[tiab])) OR ((high[tiab] OR highly[tiab]) AND myop*[tiab])) OR ((high[tiab] OR highly[tiab]) AND hyperopi*[tiab])) OR (scleral[tiab] AND buckling[tiab])) OR "posterior synechiae"[tiab])) AND ((((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab] OR cataract[tiab])) AND ("comorbidity"[mh] OR complications[tiab])))) OR "cataract/complications"[mh]))) OR ((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab] OR cataract[tiab])) AND ("comorbidity"[mh] OR comorbidities[tiab]))

Systemic Comorbidities: ((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab] OR cataract[tiab]))) AND ((((((systemic[tiab]) AND (comorbidity[tiab] OR comorbidities[tiab]))) OR (("systemic comorbidity"[tiab]) OR "systemic comorbidities"[tiab]))) OR ((hypertension[tiab] OR diabetes[tiab] OR diabetic[tiab] OR myocardial infarct[tiab] OR cardiac[tiab] OR asthma[tiab] OR thyroid disease[tiab] OR thyroid[tiab] OR hiv[tiab] OR "renal disease"[tiab] OR angina[tiab] OR cancer[tiab] OR stroke[tiab] OR "chronic disease"[tiab] OR anticoagulants[mh] OR "platelet aggregation inhibitors"[mh])))

Cataract Surgery & Vitreoretinal Surgery: ((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab] AND cataract[tiab]))) AND (((("vitrectomy"[tiab] OR "vitreoretinal surgery"[tiab])) OR (vitreoretinal[tiab] AND (surgery[tiab] OR surgeries[tiab]))) OR "vitrectomy"[mh])

Cataract in the Functionally Monocular Patient: ((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab]))) AND (Vision, Monocular[mh])

Presbyopia-correcting intraocular lenses: ("presbyopia"[mh]) AND ("lenses, intraocular"[mh] OR "intraocular lenses"[tiab])

Simultaneous Bilateral Cataract Surgery: ((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab]))) AND (bilateral[tiab] OR "same-day"[tiab] OR simultaneous[tiab] OR sequential[tiab]))

Postoperative Management, Postoperative Follow-up: ("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab]) AND ("Postoperative Care"[mh]) AND ("time factors" [mh])

Posterior Capsular Opacification: ("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab]) AND ("posterior capsular opacification"[tiab])

Cost of Cataract Sx: (((("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab])))) AND (("cost benefit analysis"[mh] OR "cost control"[mh] OR "cost savings"[mh] OR cost[tiab]))

Nutrition: ((((("cataract"[majr]) OR "cataract/epidemiology"[mh]) OR ("cataract/prevention and control"[mh]))) AND (((("nutrition assessment"[mh]) OR ("diet"[mh]) OR (diet surveys[mh]) OR ("nutritional physiological phenomena"[mh]) OR (fruit[mh]) OR (vegetables[mh]) OR ("vitamins"[mh]) OR ("minerals"[mh]) OR ("antioxidants"[mh]) OR ("dietary supplements"[mh]) OR ("beta carotene"[mh]) OR ("riboflavin"[mh]) OR ("niacin"[mh]) OR ("ascorbic acid"[mh]) OR ("vitamin e"[mh]))))

Cataract Surgery & Uveitis: ("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab]) AND (Uveitis[mh] OR uveitis[tiab])

Cataract Surgery & Immunosuppression: ("cataract extraction"[mh] OR "cataract surgery"[tiab] OR "cataract extraction"[tiab]) AND "Immunosuppression"[Mesh]

LIST OF ABBREVIATIONS

ADVS: Activities of Daily Vision Scale

AMD: age-related macular degeneration

AREDS: Age-Related Eye Disease Study

ASCRS: American Society of Cataract and Refractive Surgery

CDVA: corrected distance visual acuity

CME: cystoid macular edema

CTR: capsule tension ring

D: diopter

DME: diabetic macular edema

DMEK: Descemet membrane endothelial keratoplasty

DSBCS: delayed bilateral cataract surgery

DSEK: Descemet stripping endothelial keratoplasty

ECCE: extracapsular cataract extraction

EDOF: extended depth of focus

ESCRS: European Society of Cataract and Refractive Surgeons

EVS: Endophthalmitis Vitrectomy Study

FEMCAT: femtosecond laser-assisted versus phacoemulsification cataract surgery

FLACS: femtosecond laser-assisted cataract surgery

HORV: hemorrhagic occlusive retinal vasculitis

HSM: heparin-surface-modified

IFIS: intraoperative floppy iris syndrome

IOL: intraocular lens

IOP: intraocular pressure

IRIS: Intelligent Research in Sight

ISBCS: immediate sequential bilateral cataract surgery

IV: intravenous

LASIK: Laser-assisted in situ keratomileusis

LEC: lens epithelial cells

MIGS: minimally invasive glaucoma surgery

MIPS: merit-based incentive payment system

MSICS: manual small-incision cataract extraction

Nd:YAG: neodymium: yttrium-aluminum-garnet

NEI-VFQ: National Eye Institute-Visual Function Questionnaire

NEON: National Eyecare Outcomes Network

NSAID: nonsteroidal anti-inflammatory drug

OCT: optical coherence tomography

OVD: ophthalmic viscosurgical device

PCO: posterior capsular opacification

PK: penetrating keratoplasty

PMMA: polymethyl methacrylate

PORT: Patient Outcomes Research Team

PPP: Preferred Practice Pattern

PPV: Pars plana vitrectomy

PRK: Photorefractive keratectomy

PROM: Patient-reported outcome measure

PSC: posterior subcapsular cataract

QALY: quality-adjusted life year

RCT: randomized controlled trial

RD: retinal detachment

RK: radial keratotomy

TASS: toxic anterior segment syndrome

TPSS: toxic posterior segment syndrome

UDVA: uncorrected distance visual acuity

UGH: Uveitis, Glaucoma, Hyphema

VF-14: visual function index

VF-8R: visual function index

RELATED ACADEMY MATERIALS

Basic and Clinical Science Course
       Clinical Optics (Section 3, 2021-2022)
       Lens and Cataract (Section 11, 2021–2022)
Focal Points
       Cataract Surgery in the Developing World (2011)
       Diagnosis and Management of Cataract after Vitrectomy (2016)
       Femtosecond Laser-assisted Cataract Surgery (2015)
       Pseudophakic Cystoid Macular Edema (2012)
Patient Education Booklets
       Cataract Surgery
       Enhanced Lens Options for Cataract Surgery
Patient Education Brochures
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