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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 May 2016. 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 2016. 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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FINANCIAL DISCLOSURES

In compliance with the Council of Medical Specialty Societies' Code for Interactions with Companies (available at www.cmss.org/codeforinteractions.aspx), 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 (57%) of the members of the Cataract and Anterior Segment Preferred Practice Pattern Panel 2015–2016 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 August 2016 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 July 2015 in PubMed and the Cochrane databases. Complete details of the literature searches are available in Appendix 5.

HIGHLIGHTED FINDINGS AND RECOMMENDATIONS FOR CARE

Symptomatic cataract is a surgical disease. Dietary intake and nutritional supplements have demonstrated minimal to no effect in the prevention or treatment of cataract. *(III, good quality, strong recommendation)*

The standard of care in cataract surgery in the United States is a small-incision phacoemulsification with foldable intraocular lens (IOL) implantation. It is a standard of care that has withstood the test of time.

Refractive cataract surgery has the potential to reduce a patient's dependence on eyeglasses and contact lenses for distance, intermediate, and near vision.

Intraocular lens technologies and surgical approaches to implanting lenses continue to improve.

Femtosecond laser-assisted cataract surgery (FLACS) increases the circularity and centration of the capsulorrhexis and reduces the amount of ultrasonic energy required to remove a cataract. However, the technology may not yet be cost-effective, and the overall risk profile has not yet been shown to be superior to that of standard phacoemulsification.

The use of topical nonsteroidal anti-inflammatory drugs (NSAIDs) is controversial, with evidence suggesting that NSAIDs only be used for the prevention of cystoid macular edema (CME) in patients with diabetic retinopathy or other high-risk ocular comorbidities.

Increasing evidence demonstrates that intracameral antibiotics reduce the risk of postoperative bacterial endophthalmitis.

Surgeons should recognize and prepare to manage high-risk characteristics that may complicate cataract surgery. New risks may become apparent as new technologies come to market. One example is capsular damage with rapid development of a complicated cataract associated with intravitreal injections.

Toxic anterior segment syndrome (TASS) may be confused with infectious endophthalmitis. However, TASS has an earlier onset, is associated with limbus-to-limbus corneal edema, and responds to corticosteroids.

INTRODUCTION

DISEASE DEFINITION

A cataract is a degradation of the optical quality of the crystalline lens that affects vision. Most cataracts are related to aging. They 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 the 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 as well as other treatment alternatives to enable the patient to make an informed decision about treatment options.
- Establish criteria for a successful treatment outcome with the patient
- 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 a mutually agreeable time between the patient and surgeon.
- Perform surgery when indicated for management of coexistent ocular disease (e.g. macular degeneration or diabetic retinopathy)
- Provide appropriate postoperative care, visual rehabilitation, and treatment of any complications

BACKGROUND

PREVALENCE

The risk of cataracts increases with each decade of life starting around age 40.[4] Cataracts are the leading cause of visual impairment among Americans of African, Hispanic/Latino, and European descent and are the leading cause of treatable blindness among Americans of African descent age 40 and older.[5,6] In the United States, cataracts account for approximately 50% of visual impairment in adults over the age of 40,[5] affecting 24.4 million Americans,[4] or about 1 in every 6 people in this age range. In 2010, half of white Americans had cataracts by 75 years of age, and 70% of white Americans, 61% of Hispanic Americans, and 53% of black Americans had cataracts by 80 years of age.[4] In the United States, the number of people with cataracts is forecasted to double from 24.4 million to about 50 million by the year 2050.[4] Cataracts are the leading cause of blindness worldwide.[7]

There are several different types of cataracts (e.g., nuclear, cortical, subcapsular [anterior and posterior], and mixed). Each type has its own anatomical location, pathology, and risk factors for development. Several systems are available to classify and grade lens opacities,[8-12] but variations in grading systems make comparing prevalence rates between studies difficult.[13]

Nuclear cataracts consist of a central opacification or discoloration that interferes with visual function. There are different types of nuclear cataracts, accompanied by either brunescence, opalescence, or both.[14] The degree of brunescence may be a helpful indicator of the hardness of the lens. Nuclear cataracts tend to progress slowly and affect distance vision more than near vision. Nuclear cataracts may induce myopia or a reduction in hyperopia. In advanced cases, the lens becomes brown and opaque.

Cortical cataracts can be central or peripheral and sometimes are best visualized by retroillumination or retinoscopy. They can be spoke-like or nummular in appearance. Patients with this type of 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 cataracts (PSCs) can cause substantial visual impairment if they involve the axial region of the lens. Posterior subcapsular cataracts are found more often in younger patients than either nuclear or cortical cataracts. Patients often have glare and poor vision in bright light, and near vision is typically more affected than distance due to miosis with near accommodation.

Two population-based studies found that of the three types, cataract surgery is most frequently performed on PSCs.[15,16] In an older population (mean age 79 years) undergoing cataract surgery, the nuclear type is most frequently encountered.[17]

Studies have found racial differences in the prevalence of different cataract types.[18-22] The risk of cataract (particularly cortical) is higher in women and increases with age in the majority of prevalence studies.[7,20,23-25]

RISK FACTORS

Numerous potential risk factors have been linked with cataract development and are listed in Table 1. The most common risk factors include diabetes mellitus; long-term use of topical, systemic, intravitreal, inhaled or oral corticosteroids; prior intraocular surgery; and lower level of education achieved.[26-38]

Most studies are observational and strongly suggest an association, but they fail to prove a causative effect because they do not measure exposure to the risk factor in a standardized fashion or, in some cases, do not describe the type of cataract.[26,39]

TABLE 1   FACTORS ASSOCIATED WITH INCREASED RISK OF CATARACTS

Cataract Type	Associated Risk Factor	Type of Study	Risk
Cortical	Diabetes	Observational[7,20,32-34,40-42]	Increased risk
	Family history	Observational[20,43-47]	Increased risk
	Hypertension	Observational[34]	Increased risk
	Ionizing radiation (low and high dose)	Observational[36]	Increased risk
	Myopia (>1 D)	Observational[42,48,49]	Increased risk
	Obesity	Observational[34,50,51]	Increased risk
	Systemic corticosteroid use	Observational[29]	Increased risk
	Ultraviolet-B light exposure	Observational[23,42,43,52]	Increased risk
Nuclear	Diabetes	Observational[34,42]	Increased risk
	Obesity	Observational[53]	Increased risk
	Myopia	Observational[7,20,42,54-57]	Increased risk
	Family history	Observational[43,46,58,59]	Increased risk
	Hypertension	Observational[60]	Increased risk if taking topical or systemic beta blockers
	Prior PPV	Observational[38,61,62]	Increased risk
	Smoking	Observational[7,42,48,63-69]	Increased risk
	Tobacco (smokeless)	Observational[70]	Increased risk
	Ultraviolet-B light exposure	Case-control[71]	Increased risk

TABLE 1   FACTORS ASSOCIATED WITH INCREASED RISK OF CATARACTS (CONTINUED)

Cataract Type	Associated Risk Factor	Type of Study	Risk
Posterior subcapsular	Inhaled corticosteroid use	Population-based cross-sectional[27]	Increased risk in patients age ≥49
	Ionizing radiation (low and high dose)	Observational[36,72]	Increased risk
	Obesity	Observational[50,53]	Increased risk
	Ocular trauma	Cross-sectional[73]	Increased risk
	Prior PPV	Observational[38]	Increased risk
	Retinitis pigmentosa	Case series[74-76]	Increased risk
	Topical corticosteroid use	Case series[77]	Increased risk
	Systemic corticosteroid use	Observational[31]	Increased risk
	Myopia	Observational[7,42,54,55,57,78]	Increased risk
	Hypertension	Observational[7,78]	Increased risk
	Diabetes	Observational[7,20,34,40,41]	Increased risk
	Smoking	Observational[68,69]	Increased risk
	Trauma	Observational[73]	Increased risk
Mixed	Prior PPV	Observational[38]	Increased risk
	Tobacco use (smoking and smokeless)	Observational[70]	Increased risk
	Ultraviolet-B light exposure	Observational[23]	Increased risk
	Hypertension	Observational[7]	Increased risk
	Diabetes	Observational[20,40]	Increased risk
Subtypes not identified in study	Aspirin use	Randomized trials[79-82]	No evidence of benefit
		Observational[20,83]	Increased risk
		Observational[29,84]	Decreased risk
	Diabetes	Observational[33,34]	Increased risk
	Inhaled corticosteroid use	Case-control[28,30]	Increased risk in patients age ≥40
		Case-control[85]	Increased risk in patients age ≥65
		Case-control[86]	Increased risk in patients age ≥70
	Nasal corticosteroid use	Case-control[87]	No increased risk
	Intravitreal corticosteroids	Case-control[88,89]	Increased risk
	Ionizing radiation (low and high dose)	Observational[35,72]	Increased risk
	Smoking	Observational[69,90,91]	Increased risk
	Inactivity	Observational[92,93]	Increased risk
	Lower education	Observational[20,40,94,95]	Increased risk
	Ocular inflammatory disease	Observational[96]	Increased risk

D = diopter; PPV = pars plana vitrectomy

NATURAL HISTORY

Cataracts are variable and unpredictable. Any portion of the lens can become opaque. With age, the lens increases in thickness and weight. Continued production of lens fibers causes hardening and compression of the nucleus, known as nuclear sclerosis. Subsequently, the lens proteins undergo modification and aggregation, and they develop a yellow-to-brown coloration, which changes the transparency and refractive index of the lens. Nuclear sclerosis and yellowing are considered part of the aging process.

Cataracts typically progress. Once visual acuity and function decline, the natural history progresses with no chance of recovery. In three studies, each using different scales for progression of cataracts, there is convincing evidence that cataracts progress over time. In the Barbados Eye Studies, individuals with pre-existing lens opacities had cumulative 9-year progression rates of 22% for cortical, 18% for nuclear, and 26% for PSC opacities.[25] The Melbourne Visual Impairment Project reported cumulative 5-year progression rates of 14% for cortical, 19% for nuclear, and 20% for PSC opacities.[97] In the Longitudinal Study of Cataract, individuals with pre-existing lens opacities had cumulative 5-year progression rates of 16% for cortical, 46% for nuclear, and 55% for PSC opacities.[98,99]

VISUAL FUNCTION AND QUALITY OF LIFE

The multiple components of visual function include central near, intermediate, and distance visual acuity; peripheral vision; visual search; binocular vision; depth perception; contrast sensitivity; color perception; dark adaptation; and visual processing speed.[100] Visual function also can be measured in terms of patient-reported functional disability caused by visual impairment.[101-105] 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 observational studies consistently show that cataract surgery has a substantial beneficial impact on vision-dependent functioning. Up to 90% of patients undergoing first-eye cataract surgery note improvement in functional status and satisfaction with vision.[106-109] Several studies report an association between improved visual function after cataract surgery and an improved health-related quality of life.[103,110-113] Visual function plays an important role in physical performance and well-being,[114-116] particularly in terms of mobility.[110,117] The 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.[118] Examples include nighttime driving and daytime driving as well as community and home activities. A long-term (10-year) evaluation of patients in the Blue Mountains Study found that cataract surgery patients had a significant improvement in the mental health domain scores from the SF-36 questionnaire.[119] Cataract surgery may also help alleviate insomnia.[120,121]

Visual impairment, such as poor depth perception and low contrast sensitivity, is an important risk factor for falls[122,123] and hip fractures.[124,125] In a randomized controlled trial, first-eye cataract surgery reduced the rate of falling and fracture by 34% over a 12-month period.[110,126] Similar improvement following second-eye surgery has also been confirmed.[117,127] Visual loss from cataracts and the increased risk of falls are both contributing factors for nursing home placement.[128] A decrease in visual acuity and contrast sensitivity is associated with driving difficulties.[100,129-132] Drivers with visually significant cataracts are 2.5 times more likely to have an at-fault motor vehicle crash over a 5-year period compared with drivers without cataracts.[133] 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 undergo surgery in a 4- to 6-year follow-up period.[134,135] One large study that assessed patients' visual function pre- and postoperatively found the largest improvements in "driving during the day," "self-care activities," and "driving during the night."[136] Studies also show a reduction in mortality after cataract surgery[137-139] and evidence that waiting more than 4 months to perform cataract surgery after it is clearly indicated and scheduled can also result in increased vision-related complications, such as falls and accidents.[140,141]

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.[142,143]

Improved visual function as a result of cataract surgery can be characterized by the following:

◆ Better optically corrected vision
◆ Better uncorrected vision with reduced eyeglass dependence
◆ Increased ability to read or do near work
◆ Reduced glare (glare is a side effect of some intraocular lenses [IOLs])
◆ Improved ability to function in dim levels of light
◆ Improved depth perception and binocular vision by elimination of anisometropia and achievement of good functional acuity in both eyes
◆ Improved color vision
◆ Improved peripheral vision

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

◆ Increased ability to perform activities of daily living
◆ Increased ability to continue or resume an occupation
◆ Increased mobility (walking, driving)

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

◆ Improved self-esteem and independence
◆ Improved injury avoidance
◆ Better social engagement
◆ Relief from fear of blindness
◆ Reduced fear of falling

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
◆ 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 a cataract is to determine 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 contribute to visual impairment.

Evaluation of Visual Impairment

The impact of a cataract on visual function can be subjectively assessed by self-reported functional status or difficulty with vision. However, it is important to recognize that patients may adapt to their visual impairment and may fail to notice functional decline that accompanies the insidious progression of a typical cataract. Visual function may be assessed using tests that measure contrast sensitivity, glare disability, or visual acuity at near and distance. With newer technology, it is also possible to objectively measure higher-order aberrations from cataracts that compromise visual acuity and quality.[144,145]

There is no single test or measure that adequately describes the effect of a cataract on a patient's visual status or functional ability.[146] Similarly, no single test can properly define the threshold

for performing cataract surgery. The Snellen visual acuity chart is an excellent tool for testing distance refractive error (e.g., myopia, hyperopia, astigmatism) in healthy eyes, and it is widely used clinically. Poor preoperative visual acuity correlates with significant postoperative functional improvement in many patients with cataract.[146] However, testing only at distance with high-contrast letters viewed in low-ambient lighting conditions underestimates the functional problems in common real-life situations. For example, reading (especially in poor-contrast environments), daytime or nighttime glare conditions, halos and starbursts at night, and impaired optical quality causing monocular diplopia and ghosting are all important indicators.[101] 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.[106,147]

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.[102,148-150] For example, visual functional status indices such as the Activities of Daily Vision Scale (ADVS) and the Visual Function Index (VF-14) have been shown to better correlate with functional visual improvement after cataract surgery than measurement of Snellen visual acuity.[101]

Two main categories of validated questionnaires for measuring function exist: those that measure general health status (e.g., Short Form-36,[151] Quality of Well-Being Scale[149]) and vision-specific measures. Questionnaires that measure general health status are less strongly correlated with improvement following cataract surgery than are vision-specific measures.[149,152] Examples of vision-specific instruments developed or used for cataract evaluation include the Visual Activities Questionnaire,[153] the ADVS,[148] the VF-14[101] and modified versions (e.g., VF-8R),[154] the National Eye Institute Visual Function Questionnaire (NEI-VFQ),[155,156] and the Catquest-9SF.[104]

These questionnaires have been utilized as research tools to provide a standardized approach to assessing visual function, and they can be analyzed and compared across various time periods and populations. More recently, adaptations of some of these questionnaires for application in other cultures or languages have also been developed.[157-159] Responses to these questionnaires are not intended to be the sole basis for determining the need for surgery. For example, some patients with clinically significant cataract who would experience worthwhile visual gain from surgery may not perceive a functional problem listed on the questionnaire.[160] However, visual function questionnaires can contribute to the overall evaluation of a patient who has a cataract and may aid in the therapeutic decision-making process. At this time, there is no single universally accepted questionnaire in clinical use for assessing functional-vision impairment. The assessment of functional status, which may be performed using a variety of methods, is a pertinent part of the patient's evaluation. Patients with fairly symmetric cataract formation are typically least aware of their visual impairment.

Ophthalmic Evaluation

The comprehensive evaluation (history and physical examination) includes those components of the comprehensive adult medical eye evaluation[161] 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 current correction (the power of the present correction recorded) at distance and, when appropriate, at near
- Measurement of best-corrected distance visual acuity
- Assessment of the degree of anisometropia after refraction
- Glare testing when indicated
- Assessment of pupillary function
- Examination of ocular alignment and motility
- External examination (eyelids, lashes, lacrimal apparatus, orbit)
- Measurement of intraocular pressure (IOP)

◆ Slit-lamp biomicroscopy of the anterior segment, examination of the lens, vitreous, macula, peripheral retina, and optic nerve through a dilated pupil
◆ Assessment of relevant aspects of the patient's mental and physical status (i.e., cooperation and ability to lie flat)
◆ Assessment of any barriers to communication (language or hearing impairment)

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. In a large majority of patients, the ophthalmologist is able to determine whether the cataract is responsible for the patient's visual loss by comparing slit-lamp biomicroscopy findings with the patient's specific symptoms.

Occasionally, a patient presents with visual symptoms disproportionate to the degree of cataract formation. Visual acuity testing alone does not quantify certain visual symptoms, such as disabilities due to glare and reduced contrast sensitivity.[162-166] In addition, measurements taken in a darkened examination lane with a high-contrast, brightly illuminated target may substantially underestimate the functional problems experienced under a wide variety of lighting and contrast conditions. Visual acuity can be measured and compared with room lights on and off.

Glare testing determines the degree of visual impairment in the presence of a light source located in the patient's visual field. Cataracts may produce a severe visual disability in brightly lit situations, such as sunny daytime lighting or lighting from oncoming automobile headlamps at night. Visual acuity in some patients with cataracts may be normal or near normal when tested in a darkened examination room, but when these patients are retested together with a source of glare, visual acuity (or contrast sensitivity) may drop significantly.[167] However, significant reduction in visual acuity with glare testing is by no means specific for cataract as the etiology but rather may also be secondary to other conditions, such as ocular surface disease. Accordingly, correlation with slit-lamp/funduscopic examination 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.[168]

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 visual acuity testing. For the patient who complains of visual loss and also has lens changes, contrast sensitivity testing may demonstrate a significant loss of visual function that is not appreciated by Snellen visual acuity testing alone.[163,164,169,170] Decreased contrast sensitivity (as well as decreased Snellen visual acuity) may occur for a number of reasons, and therefore, this test is not a specific indicator of visual loss due to a cataract. In spite of substantial progress over the past few years, there remains no standard or universally preferred method for testing contrast sensitivity.

Ocular wavefront testing has demonstrated that even relatively mild cataracts may be associated with a significant increase in 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 with cataract formation, leading to a decrease in contrast sensitivity.[171,172] This may explain the symptoms reported by some older individuals who have a mild lens opacity and reasonably good best-corrected visual acuity (BCVA). Measuring corneal aberrometry might be useful in IOL selection and assist in selecting appropriate advanced technology IOL candidates.[173]

Biomicroscopic and ophthalmoscopic examinations of the macular region do not necessarily predict macular function when the macula is abnormal. Potential acuity testing helps predict the visual acuity following cataract surgery and may provide helpful information in certain situations.[174,175] Potential acuity tests perform less reliably in patients with cataract who present with visual acuity worse than 20/100.[174,176-178]

Subjective potential acuity tests include the potential acuity meter, laser interferometer, and scanning laser ophthalmoscope. Each projects an image onto the retina through relatively clear regions of the lens, and the patient is asked to identify the letters or pattern.[179] Newer devices may provide more accurate assessments.[180] Other tests, such as the potential acuity pinhole, require the patient to read a brightly illuminated near card through a trial frame at near.[174,181,182] The near-card pinhole methods are simpler and less expensive than the technology-dependent potential acuity meter and scanning laser ophthalmoscope. When the preoperative distance acuity is 20/100 or better, the Retinal Acuity Meter may more accurately predict the postoperative visual acuity in the presence of ocular comorbidity.[181]

An assessment of tear function is also important. *(II+, good quality, strong recommendation)* 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 indications of tear dysfunction that may compromise the postoperative result.

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

Specular microscopy and corneal pachymetry are used to evaluate patients with known preoperative corneal endothelial disease in an effort to determine whether the cornea is likely to remain clear following cataract surgery. These tests are usually not necessary. However, they may be useful for eyes in which the corneal endothelial function is suspected to be abnormal as a result of endothelial corneal dystrophies, previous ocular surgery, or trauma. Several studies suggest that specular microscopy has relatively low accuracy in predicting corneal clarity following cataract surgery.[183,184]

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 performing limbal relaxing incisions or astigmatic keratotomy in conjunction with cataract surgery. Additionally, Scheimpflug devices can evaluate posterior corneal astigmatism to aid in toric IOL selection or astigmatism management.[185-188] Keratometry is a simple evaluation that can help assess the degree of surface irregularity (e.g., epithelial basement membrane dystrophy), which can contribute to visual disability.

Optical coherence tomography (OCT)[189,190] and fluorescein angiography may be helpful prior to cataract surgery to evaluate foveal architecture or to identify the presence of concomitant retinal disease and anterior segment disorders, such as posterior polar cataracts,[191] even when the foveal center and immediately surrounding areas appear normal on direct examination.

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, or posterior staphyloma. Visual fields, external and fundus photography, and special color-vision testing have not been shown to be of value in routinely evaluating patients before cataract surgery.

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 are affected by cataracts in the United States.[4]

Several studies show a linkage of smoking with nuclear sclerosis and demonstrated a dose-response effect.[7,48,63-65,68,69,90,192,193] Smoking is also associated with an increased risk for PSC and, to a lesser degree, cortical cataract..[20,63] Findings from studies indicate a reduced risk of cataracts and cataract surgery in past smokers compared with current smokers, demonstrating a benefit from smoking cessation.[64,65,90,91,194] A recent study demonstrates that the risk may persist

for decades in heavy smokers.[91] Thus, patients should be warned of this risk and counseled to stop smoking.[42,91,195] *(II+, good quality, strong recommendation)*

Cumulative lifetime exposure to ultraviolet-B radiation has been associated with lens opacities.[23,52,71,196,197] Therefore, brimmed hats and ultraviolet-B blocking sunglasses are reasonable precautions to recommend to patients.[42] *(II-, good quality, strong recommendation)*

A Cochrane review of nine trials involving 112,272 individuals with follow-up ranging from 2.1 to 12 years found no evidence to support high doses of vitamin E, vitamin C, or beta-carotene in preventing the progression or development of cataracts.[198] A recent observational cohort study of men found that high doses of vitamins C and E increased the risk of age-related cataract (ARC).[199] Another study in a cohort of women found an increased risk of ARC with high doses of vitamin C.[200] A recent randomized clinical trial found long-term daily supplementation with selenium and/or vitamin E unlikely to have a large beneficial effect on ARC.[201] Daily supplementation with lutein/zeaxanthin showed no significant effect on rates of cataract surgery or vision loss in the Age-Related Eye Disease Study 2 (AREDS2) trial.[202] There is little evidence that long-term use of high-dose antioxidant supplements decreases the progression of ARC, however, a recent twins study suggested that oral vitamin C intake was protective of nuclear sclerosis.[203] Therefore, the evidence to date is contradictory.

The role of multivitamin and mineral supplements in reducing ARC is controversial. In 2006, an Evidence-Based Practice Center systematic review of the literature sponsored by the Agency for Health Research and Quality found no benefit from multivitamin/mineral supplements in preventing cataracts.[204] However, a recent systematic review of the literature found evidence supporting the role of multivitamins/mineral supplements in reducing the risk of ARC.[205] A randomized trial of multivitamin/mineral supplementation with 9 years of follow-up found fewer nuclear cataracts (34% reduction) but more PSCs (twofold increase) in the group taking supplements.[206] A recent large-scale randomized controlled trial of male physicians demonstrated that long-term daily multivitamin use modestly reduced the incidence of nuclear cataract.[207] The Age-Related Eye Disease Study (AREDS), a clinic-based cohort prospective study, showed Centrum multivitamin use was associated with decreased risk of nuclear cataract and no increased risk for PSC.[20] Thus, there is moderate evidence that multivitamin/mineral supplements may decrease the risk of nuclear cataract.

Several observational studies demonstrate the benefit of healthy diet in prevention of cataracts.[208-211] Appendix 3 summarizes studies of nutrition and cataract.

Long-term increased physical activity and exercise may decrease the risk of cataract, based on two prospective observational cohort studies.[93,212] Conversely, high inactivity levels or prolonged sitting may be associated with increased cataract formation.[92,93]

In the literature, the association between cataracts and statins is conflicting. A recent meta-analysis of 14 studies pertaining to statins and cataracts demonstrated a relative protective effect of statins in preventing the progression of cataracts.[213] Contrary to this are studies that show an increased risk of cataracts with statin use, none of which were included in the above meta-analysis.[214-217] Thus, the studies to date have conflicting results regarding the relationship between statins and cataracts.

Long-term users of inhaled or oral corticosteroids are at higher risk for cataract formation.[27-31] Nasal corticosteroids are less likely to cause progression of cataracts according to a recent comprehensive systematic review of the literature.[87]

Presence of diabetes mellitus,[7,20,32-34] hypertension,[34,60,78] obesity,[34,50,51] and metabolic syndrome (diabetes, hypertension, obesity, and dyslipidemia)[218-220] have been reported to show an increased risk of cataract in multiple observational studies. Prevention and treatment of these conditions may reduce the risk of cataract.

Lastly, several studies have demonstrated an increased risk of cataract with blunt and penetrating trauma.[73,221] Therefore, recommending safety eyeglasses in high-risk activities at work or recreation is reasonable. *(III, good quality, strong recommendation)*

Nonsurgical Management

Management of a visually significant cataract is primarily surgical. Nonsurgical management includes counseling patients about cataract-related visual symptoms, providing reassurance about the cause of the visual disability, and prescribing new eyeglasses to correct a lens-induced change in refractive error. Surgery can be deferred in some cases by prescribing mydriatic agents to reduce symptoms associated with small centrally located cataracts or by prescribing contact lenses when uniocular cataract development causes symptomatic anisometropia but before there is a significant degradation in visual acuity.

Currently, there are no pharmacological treatments known to eliminate existing cataracts or retard their progression in humans. Ophthalmologists should advise patients that at this time there is insufficient evidence to support the use of pharmacological treatments for cataract. *(III, good quality, strong recommendation)*

Patients may reduce the risk of cataract development or progression by reducing exposure to known risk factors, such as through smoking cessation or improving diabetes control.

A physician's advice to quit smoking is an important motivator in a patient's attempt to stop.[222-225] Cataracts, therefore, give the ophthalmologist an opportunity to discuss both the ocular benefits and general health benefits of smoking cessation.

Patients who are long-term users of oral and inhaled corticosteroids should be informed of the increased risk of cataract formation[28-31,86,226] *(II+, moderate quality, strong recommendation)* and may wish to discuss alternative medications with their primary care physician. Brimmed hats and ultraviolet-B blocking sunglasses are reasonable precautions to consider, but there is no interventional trial that proves this will reduce the risk of cataract formation.[42,227]

Surgical Management

The predominant method of cataract surgery in the developed world is sutureless small-incision phacoemulsification with foldable intraocular lens (IOL) implantation.[228] *(I+, good quality, strong recommendation)* In randomized clinical trials, it produces better outcomes than manual extracapsular cataract extraction (ECCE) with incision closure by sutures.[229] In the developing world, ECCE and intracapsular cataract extraction (ICCE) remain popular because of their cost-effectiveness, and sutureless ECCE with IOL performed very well in comparison to phacoemulsification with a foldable IOL in one randomized clinical trial.[230] Extracapsular cataract extraction with IOL implantation was shown to produce a better visual outcome than ICCE with optical rehabilitation with aphakic eyeglasses.[229]

Indications for Surgery

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

◆ There is clinically significant anisometropia in the presence of a cataract
◆ The lens opacity interferes with optimal diagnosis or management of posterior segment conditions
◆ The lens causes inflammation or secondary glaucoma (phacolytic, lens particle, phacoanaphylactic)
◆ The lens induces or risks angle closure

Contraindications to Surgery

Surgery for a visually impairing 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 Medical Evaluation

The ophthalmologist who is to perform the cataract surgery should consider all of the following responsibilities:[231,232]

◆ To examine the patient preoperatively (see Ophthalmic Evaluation section)
◆ To ensure that the documented evaluation accurately reflects the symptoms, findings, and indications for treatment
◆ To 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 anticipated refractive outcome and the patient's surgical experience[233]
◆ To review the results of the presurgical evaluation with the patient or the patient's surrogate decision maker
◆ To counsel the patient about target postoperative refractive options, such as bilateral emmetropia, bilateral myopia, or monovision, and assist in choosing an option, such as astigmatism correction or a multifocal IOL, that will work best given the ophthalmic history and patient's desires
◆ To formulate a plan, including selection of appropriate anesthesia, surgical approach, and IOL design and power
◆ To formulate a postoperative care plan and inform the patient or the patient's surrogate decision maker of these arrangements (setting of care, care provider)
◆ To answer the patient's questions about the surgery and care, including associated costs

Ideally, the operating ophthalmologist should perform the preoperative evaluation, because this will allow the surgeon to formulate the surgical plan and establish a relationship with the patient prior to surgery. *(III, good quality, strong recommendation)* Although the ophthalmologist is responsible for the examination and review of the data, certain aspects of data collection may be conducted by another trained individual under the ophthalmologist's supervision and with his or her review.[231,232]

Patients undergoing cataract surgery should have a preoperative medical evaluation, including history and physical examination with consideration of the risk factors for undergoing the planned anesthesia. *(III, good quality, strong recommendation)* 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 should be strongly considered.[234]

Routine preoperative laboratory testing in association with the history and physical examination is not indicated.[235] *(I+, good quality, strong recommendation)* The Study of Medical Testing for Cataract Surgery demonstrated that routine medical testing did not reduce perioperative morbidity and mortality. Directed testing may be recommended as appropriate for a particular surgical candidate with particular medical problems.[235,236]

Biometry and Intraocular Lens Power Calculation

Accurate measurement of axial length and central corneal power, combined with an appropriate IOL selection based on a power calculation formula, is the minimal requirement to achieve the targeted postoperative refraction. *(III, good quality, strong recommendation)* A-scan ultrasonography or optical biometry is used to measure axial length. A-scan ultrasonography is performed using either an applanation or immersion technique. In A-scan ultrasonography by applanation, the ultrasound probe compresses the cornea by variable amounts and there is both a variable and artificial shortening of axial length; the accuracy and overall consistency of this method are highly dependent on the skill and experience of the operator.[237-239] When the immersion technique is used, the

ultrasound probe does not come in direct contact with the cornea, making the measurements more consistent and accurate.

Optical biometry is a high-resolution noncontact method for measuring axial length that uses partial coherence interferometry rather than ultrasound. It is significantly more accurate and consistent than contact (applanation) A-scan biometry.[237,240,241] Optical biometry was initially considered comparable to immersion A-scan biometry, but it has since been shown to produce improved refractive outcomes. The patient's spherical equivalent is also more likely to be closer to the target refraction.[242-244] Optical biometry has also been shown to give user-independent results.[245] Other advantages over A-scan ultrasonography include ease and speed of automated operation and the ability to measure to the center of the macula when proper fixation is achieved. A shortcoming of optical biometry is that currently it assigns a global refractive index to the entire eye rather than adjusting it according 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 with standard formulas. To compensate for this effect, approaches such as the Wang-Koch adjustment can be applied for eyes longer than 25 mm.[246] The Wang-Koch adjustment is unreliable in conjunction with the Barrett Universal II formula, or with any of the many specialized formulas, when 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.[247] Additionally, it is easier to use optical biometry than ultrasound when the patient has silicone oil in the posterior segment.[248,249] Despite recent advances in optical biometry that allow the measurement of axial length through increasingly dense cataracts,[250] A-scan biometry may be necessary to measure the axial length in certain cataracts or when patients are unable to fixate properly.[251,252] The measurement and comparison of axial length for both eyes is advisable, even if surgery is not planned for the other eye.

Formulas for calculating IOL power rely on keratometry to determine the net refractive contribution of the cornea. These measurements can be obtained by either manual or automated keratometry, or by corneal topography. Following keratorefractive surgery, the determination of true central corneal power is particularly challenging (see Cataract Surgery Following Refractive Surgery section). All devices that measure corneal power by standard methods are unable to accurately determine the total central corneal power following keratorefractive surgery to correct myopia because the posterior curvature may be unaltered. The use of standard keratometry in this setting without a compensatory adjustment will typically result in an unanticipated under- or overcorrection.

Recent-generation theoretical IOL-power calculation formulas such as Hoffer Q, Holladay, and SRK/T should be used in the IOL-selection process.[253-258] Some newer generation formulas, such as Haigis, Holladay 2, Olsen, and Barrett Universal II incorporate additional measurements such as anterior chamber depth, lens thickness, and horizontal corneal diameter in an attempt to predict more accurately the effective lens position of the IOL to be implanted.[259-261] Theoretical formulas rely on numerical constants that allow the formula to predict the effective lens position within the eye. The Haigis formula uses three separate constants that are highly specific to the individual characteristics of a specific IOL model across its power range. Although the IOL manufacturer supplies 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 being used. Optimization of lens constants for a specific IOL based on an individual surgeon's actual refractive outcome is recommended.

The surgeon should consider the patient's individual desires and needs in selecting an appropriate postoperative refractive target. *(III, good quality, strong recommendation)* Several extended-range high-plus and high-minus IOL powers are available. Patients with

high myopia, where very low-power IOLs straddle both sides of plano, may require unique lens constants for plus and minus powers that are quite different than those recommended by the manufacturer.[262,263] For the patient with extreme hyperopia requiring an IOL power in excess of the available range, piggybacking two posterior chamber IOLs has been used.[264] When this is indicated, it is preferable to use lens optics of different materials in different locations rather than inserting both IOLs inside the capsular bag. This reduces the risk of interlenticular (between the IOLs) membrane formation.[265,266] If implantation of a sulcus piggyback IOL can be delayed until the in-the-bag lens has a stable anterior chamber depth, it may improve refractive accuracy and reduce the incidence of interlenticular opacification. Intraocular lens power calculations for piggybacked IOLs as a primary procedure may be less accurate than for a single IOL because it is difficult to predict the combined effective IOL position.[267] Refractive results with piggybacking IOLs have been favorable in two small case series.[268,269] Sulcus piggyback implantation in the setting of zonular laxity may result in an unexpected hyperopic refractive result if the piggyback lens pushes the lens within the capsular bag posteriorly, thus reducing its effective power.

A corneal relaxing incision can correct small amounts of astigmatism, but for 1.0 diopter (D) or more of preoperative corneal astigmatism, toric IOL implantation should be considered.[270-272] Most toric lenses are designed for implantation within the capsular bag. Many company-specific online and machine-based calculators are available to calculate the power of the toric component of the optic. They require the input of preoperative keratometry values and the anticipated surgically induced astigmatism. Adding the contribution of the posterior cornea has been shown to improve outcome accuracy.[273-275] The final resting location of the IOL within the eye influences the effective power of the toric component of the optic, just as it does for a purely spherical lens.[276] Online formulas that calculate the effective lens position of a toric IOL require the user to input the axial length of an eye in addition to keratometry values and surgically induced astigmatism. The spherical power of a toric IOL is calculated in the usual manner.

Most modern IOLs have aspheric optics. These lenses improve mesopic and scotopic contrast sensitivity and visual quality by reducing depth of focus caused by spherical aberration.[277-281] Some surgeons match the asphericity of the IOL to be implanted to the asphericity of the cornea to maximize visual quality under dilated-pupil conditions.[282]

Intraocular lens power can be confirmed or refined intraoperatively in the aphakic and pseudophakic states through the use of intraoperative aberrometry.[283] These devices can be used to assist with axis alignment of a toric IOL as well.[284] Intraoperative aberrometry can be especially useful in eyes with a history of keratorefractive surgery, such as PRK and LASIK, although it is not as useful following radial keratotomy.[285]

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 will know 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.[286-293] Intravenous (IV) sedation is commonly used to complement the anesthesia in order to optimize the patient's surgical experience and cooperation.

Local (regional) and topical anesthesia is generally preferred, with or without sedation/analgesia. General anesthesia may be utilized if needed for patients with medical, psychosocial, or surgical indications. In a review of studies on cataract surgery using local anesthesia, investigators have concluded that a variety of anesthesia strategies for cataract surgery are safe and effective and that they provide good or excellent intraoperative pain control.[286,289-297] *(I++, good quality, strong recommendation)*

Anesthesia techniques with needle injections or blunt cannula may be associated with complications such as strabismus, globe perforation, retrobulbar hemorrhage, intravascular or subarachnoid injection, and macular infarction that are not encountered with topical techniques.[286,290-294] Eyes with posterior staphyloma, or prior scleral buckle, are at increased risk for globe perforation by peri- or retrobulbar injections.[298]

A Cochrane review of RCTs comparing peribulbar to retrobulbar blocks found no difference in efficacy (in terms of akinesia, anesthesia, or need for supplemental injections) or safety.[289,296] Conjunctival chemosis was more likely with peribulbar blocks, while lid hematoma was more likely with retrobulbar blocks. There was no difference in the risk for ptosis. The rates of severe local and systemic complications were very low, with one retrobulbar hemorrhage reported in a patient who had a retrobulbar block.

Another Cochrane analysis of RCTs comparing topical to sub-Tenon's anesthesia found greater intraoperative but less postoperative pain at 24 hours with topical anesthesia.[299] While statistically significant, the magnitude was not clinically relevant. There was insufficient evidence to draw conclusions about the incidence of surgical complications between the two techniques.

Many patients who have cataract surgery under topical or peribulbar regional anesthesia (especially topical) experience a variety of visual sensations, such as seeing lights, colors, movement of instruments, and the surgeon's hand or fingers. Because 3% to 18% of patients found these visual sensations disturbing, preoperative counseling about this phenomenon makes it less frightening.[300,301]

Intravenous access is recommended to treat potential adverse events when sedation/analgesic agents are administered.[302] *(I+, good quality, strong recommendation)* However, given the trend toward topical anesthesia and reduction or elimination of intravenous analgesia/sedation, IV access may be unnecessary. Topical anesthetic drops may be supplemented with intracameral lidocaine for increased pain control.[303] Monitoring during administration of anesthesia and surgery generally includes using a heart monitor, pulse oximetry, and measurement of blood pressure and respirations. These should be performed by personnel (other than the operating ophthalmologist) qualified to monitor and manage the patient's systemic status. *(III, good quality, strong recommendation)* One study of patients receiving peribulbar anesthesia found that under age 60, hypertension, pulmonary disease, renal disease, and a prior or current diagnosis of cancer correlated with the need for intervention by anesthesia personnel, while an abnormal preoperative EKG or presence of diabetes was not predictive of the need for intervention.[304] Several studies report their experience using registered nurses[305,306] or respiratory therapists trained as sedation nurses.[307] In these situations, anesthesiologist intervention was required in 2% to 9% of cases.

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.[286] *(I+, good quality, strong recommendation)* The evidence was 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.[287] Also, excessive use of IV sedatives during cataract surgery was associated with increased risk of an adverse intraoperative medical event and was an even greater risk when both IV opiates and sedatives were used.[288,308,309] Evidence is mixed on the value of oral anxiolytic medication to reduce the patient's anxiety levels when given before cataract surgery.[308-312]

In summary, given the lack of evidence for a single optimal anesthesia strategy for cataract surgery, the type of anesthesia management should be determined according to the patient's needs, the preference of the patient,[313] the anesthesia professionals, and the surgeon. *(I+, good quality, strong recommendation)*

Infection Prophylaxis

Preventing postoperative infection is very important because of the potentially severe consequences of endophthalmitis. However, controlled studies of endophthalmitis prophylaxis have been difficult to perform due to the low incidence of endophthalmitis, varied practice patterns, inconsistent definitions, and the rapid evolution of surgical techniques. Two concerns are the increasing resistance of *Staphylococcus* species (the most common cause of endophthalmitis) to a broad spectrum of antibiotics, including the latest generation fluoroquinolones, and the occurrence of acute endophthalmitis more than a week after surgery.[314-317]

Historically, the expected incidence of sporadic endophthalmitis was between 0.5 and 1 case per thousand routine cataract procedures. In 1994, an increased rate of postcataract surgery infections was reported, whereas the incidence of infection after other anterior segment procedures was reported on the decline.[318-321] Several large population studies, however, have shown a more recent steady decline in endophthalmitis risk after cataract surgery.[322,323] It has been proposed that the period of increased infection rates corresponded to the increased use of clear corneal incisions for cataract surgery, because improperly constructed clear corneal incisions are more prone to postoperative instability, leakage, and a potential influx of microbes than are sclerocorneal incisions.[324-331] On the other hand, four large case series found no greater likelihood of infection with corneal versus other types of incisions during this period.[332-335] Nevertheless, careful watertight incision construction and closure (with or without sutures) is obligatory, irrespective of surgical style, because the incidence of infection increases with wound leak.[336] *(II-, moderate quality, strong recommendation)* Other factors associated with increased rates of endophthalmitis include intraoperative rupture of the posterior capsule, vitreous loss, prolonged surgical time, immunodeficiency, active blepharitis, lacrimal duct obstruction, inferior incision location, incomplete removal of lenticular cortex, male gender, older age, previous intraocular injections, lower surgical volume, and less experienced surgeons.[322,333,336-347] Four retrospective studies suggest a greater endophthalmitis incidence with a planned ECCE when compared with cataract surgery by phacoemulsification.[347-350] However, assuming proper incision closure, there is no strong evidence that the method of cataract surgery is a major factor affecting endophthalmitis risk.

There is also no consistent evidence that any one type of IOL optic material is associated with a higher rate of infection.[326,340,347,350,351] However, polypropylene loop supports have been associated with a greater chance for infection because it appears that bacterial adherence to polypropylene exceeds that for other materials.[352,353] As a corollary, antibiotics reduce the tendency for microorganisms to adhere to the surface of IOLs.[354,355] Also, there may be a greater risk for IOL-related contamination of the anterior chamber when the IOL comes in contact with the ocular surface prior to implantation. One study suggests that when the IOL is folded into an inserting cartridge and is placed within the eye directly through the cartridge, avoiding the ocular surface, the likelihood for intraocular contamination is reduced.[356]

Although very occasional clusters of infections may be induced by contaminated surgical products,[357-362] topical drops,[363,364] or contaminated operating room environments,[365,366] the patient's periocular flora is the primary source for microbes responsible in most cases of sporadic postoperative infection.[367] Prophylactic strategies are commonly used, such as applying topical antibiotic eye drops before surgery, applying 5% povidone iodine to the conjunctival cul de sac, preparing the periocular skin with 10% povidone iodine, careful sterile draping of the eyelid margins and eyelashes, adding antibiotics to the irrigating solution, instilling intracameral antibiotics at the close of surgery, injecting subconjunctival antibiotics, and applying topical antibiotic eye drops after surgery.

Importantly, nonrandomized controlled trials and a prospective trial with the unoperated eye as the control have provided evidence that using topical 5% povidone iodine in the conjunctival cul de sac reduced the bacterial load and the incidence of postoperative infection.[368-370] Lower concentrations of povidone iodine are less effective in reducing

conjunctival bacterial colony counts.[371-373] The presence of lidocaine gel prior to povidone iodine instillation appears to diminish its antimicrobial efficacy.[374]

Although topical antibiotics prior to surgery do decrease the bacterial load on the ocular surface, 1 day was as effective as 3 days of preoperative antibiotics in one randomized study, and topical povidone iodine alone was as effective as povidone iodine combined with preoperative topical antibiotics in another randomized clinical study.[375-381] So, it is unlikely that preoperative topical antibiotics add anything to the effect of appropriately used topical 5% povidone just prior to surgery.

Systemic antibiotics are rarely used; however, certain oral fluoroquinolone antibiotics penetrate the blood/ocular barrier adequately to reach levels above the minimum inhibitory concentrations for many organisms inside the eye, and oral antibiotics that penetrate well into the eye may be used selectively.[382-385]

There is increasing evidence that supports the use of intraocular antibiotics to reduce the risk of endophthalmitis. The partially masked and randomized European Society of Cataract and Refractive Surgeons (ESCRS) study of the prophylactic effect of intracameral cefuroxime injection at the conclusion of the procedure and/or perioperative levofloxacin eye drops on the incidence of endophthalmitis after phacoemulsification was halted early because of a beneficial effect using intracameral cefuroxime. Based on data from 13,698 patients with complete follow-up records, investigators found that the odds ratio for developing endophthalmitis was 4.59 (95% CI, 1.74–12.08; P=0.002) in the group not receiving intracameral cefuroxime injection.[351] The incidence of endophthalmitis in the control group was higher than that reported in some studies from U.S. centers. An earlier retrospective study in Sweden also reported efficacy of intracameral cefuroxime in reducing postcataract endophthalmitis, as did a later prospective nonrandomized Swedish study that reported a similar endophthalmitis rate without cefuroxime and half the rate of endophthalmitis with intracameral cefuroxime.[340,386] Seventeen other retrospective studies have since reported that intracameral injection of cefazolin, cefuroxime, or moxifloxacin have reduced the incidence of postcataract endophthalmitis.[346,347,350,387-400] One study used serial aqueous taps in cataract patients to determine that a single intracameral bolus of 1 mg of vancomycin achieved aqueous drug levels exceeding the minimum inhibitory concentration for most gram-positive bacteria for longer than 24 hours. However, the use of vancomycin as an endophthalmitis prophylaxis is strongly discouraged based on the recent finding of hemorrhagic occlusive retinal vasculitis (HORV) development after seemingly uncomplicated cataract surgery.[401] Several studies support the safety of intracameral moxifloxacin injection for endophthalmitis prophylaxis, and three retrospective studies suggest efficacy.[346,347,392,400,402-404] *(I-, good quality, strong recommendation)* Mixing noncommercially formulated antibiotic solutions for intracameral use carries the risk of dilution and composition errors with potential severe toxicity.[405-410]

Unlike direct intracameral antibiotic injection, there are no corresponding studies to support the efficacy of placing antibiotics in the irrigation bottle, although this remains a common practice.[411,412] Compared with an intracameral bolus, antibiotic in the infusate has the theoretical disadvantage of achieving less predictable intraocular antibiotic concentration and duration, and the practice should be discouraged.[413] *(III, moderate quality, strong recommendation)*

Evidence of the benefit of injecting subconjunctival antibiotics at the conclusion of surgery is supported by two retrospective surveys. However, this is associated with risks that include pain, globe perforation, hemorrhage, and intraocular toxicity from subconjunctival leakage through the incision with the potential for macular infarction when aminoglycosides are used.[342,414,415]

Although the evidence is limited, retrospective studies suggest that topical antibiotic prophylaxis may be effective,[336,346] however, it does increase antibiotic resistance.[416] Survey data from 2014 (1147 respondents; 15% response rate) of the American Society for Cataract and Refractive Surgery (ASCRS) members found that topical antibiotic prophylaxis was used by 85% of respondents preoperatively and 97% of respondents postoperatively. However, the increasing use of intracameral antibiotics appears to be a

continuing trend, with 50% reporting routine use in the 2014 survey versus 30% in 2007.[417] In the 2014 survey, 83% of respondents said they would use intracameral antibiotics if an approved product were available.[344,417] With respect to timing, other studies support the practice of initiating topical antibiotics immediately following surgery rather than waiting until the first postoperative day.[321,336,418-420]

Topical fourth-generation fluoroquinolones have theoretical advantages of broad-spectrum coverage, bactericidal activity, and improved intraocular penetration, and they were the most frequent topical prophylactic antibiotics used by the ASCRS survey respondents.[411] The higher cost of these drugs should be considered in light of the absence of any strong evidence of superiority over less expensive topical or intracameral antibiotics.[421] Furthermore, one very large study based on 315,246 surgeries did not show a difference in efficacy between topical gatifloxacin, ofloxacin, or polymyxin/trimethoprim. However, the use of topical aminoglycosides was associated with double the rate of postoperative endophthalmitis, suggesting they are not a good choice for prophylaxis.[346] This study also found that although topical antibiotics did not increase the efficacy of intracameral antibiotics, the lack of antibiotics altogether had twice the incidence of postoperative endophthalmitis when compared with topical antibiotics alone, and the use of no antibiotics had four times the incidence when compared with intracameral antibiotic use.

In summary, major risk factors for endophthalmitis include older age, a leaky incision, and iatrogenic communication between the anterior and posterior segment (e.g., posterior capsular or zonular tears). A recent study also suggested that using an IOL insertion device versus folding the lens decreased the risk of postoperative endophthalmitis.[422] There is good evidence for the use of a 5% solution of povidone iodine in the conjunctival cul de sac to prevent infection.[369,423] *(II-, moderate quality, strong recommendation)*

There is mounting evidence that injecting intracameral antibiotics as a bolus at the conclusion of surgery is an efficacious method of endophthalmitis prophylaxis. The evidence supporting subconjunctival antibiotic prophylaxis is relatively weak. As an alternative to intracameral or subconjunctival injection, topical antibiotic instillation may be more protective when initiated on the day of surgery instead of on the first postoperative day. Due to the lack of sufficiently large prospective clinical trials, and the impracticality of conducting such trials, there is insufficient evidence to recommend a specific antibiotic drug or method of delivery for endophthalmitis prophylaxis. However, increasing evidence supports the role of intracameral antibiotic use.[424]

In conclusion, the surgeon must ensure that antisepsis of the periocular surface, typically with povidone iodine, is achieved and that all incisions are closed in a watertight fashion at the end of the procedure.[336] *(II-, moderate quality, strong recommendation)* It would appear that antibiotic use on the day of surgery is important rather than waiting until the next day.[336] Specific prophylactic antibiotic strategies in the perioperative period lack sufficient scientific evidence to make a recommendation at this time.

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. Common clinical findings associated with TASS 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.[425] Toxic anterior segment syndrome usually responds to anti-inflammatory medication, but permanent intraocular damage can occur. However, if there is sufficient suspicion of an infectious etiology, cultures of the anterior chamber and vitreous should be obtained to test for infectious etiologies, and antibiotic treatment should be initiated.[426] *Bacillus cereus* infection has been shown to mimic TASS findings early on. However, it will continue to worsen in spite of an early response to topical corticosteroids.[427] Toxic anterior segment syndrome typically has an earlier time course than *B. cereus* infection.

Many factors are associated with TASS, but the etiology is often difficult to prove.[425] Likely causes include heat-stable gram-negative endotoxins from municipal water supplies, chemical detergent and enzymes used to clean instruments, ointment seepage through clear corneal incisions, injected sterile water, IV solutions, a denatured (autoclaved) ophthalmic viscosurgical device ([OVD], i.e., viscoelastic residue from cannulas), solutions of nonphysiologic pH and osmolality, metal contamination of the IOL, incisional leakage from subconjunctival antibiotic, contaminated silicone oil in the vitreous cavity, ethylene oxide vitrectomy-pack sterilization, and IOL polishing compounds.[428-434] Two studies question whether residual OVDs removed by enzymatic cleaners are a cause of TASS.[435,436] The growing use of intracameral antibiotics has resulted in commensurate reports of TASS as a result, often with dilution error the documented cause.[405-409]

One study reviewed 1276 TASS cases that were reported either by questionnaire (77 centers) or site visit (54 centers) from 2005 to 2009.[437] The most common factors associated with TASS were related to inadequate cleaning and sterilization of ophthalmic instruments: inadequate flushing of phacoemulsification and irrigation/aspiration handpieces and inappropriate use of enzymatic cleaners, detergents, and ultrasound baths for cleaning and sterilizing instruments.[437] These findings were confirmed in a similar study of 1454 TASS cases.[428] A retrospective study of 26,408 consecutive cataract surgeries from a single institution during a 1-year period reported 60 cases of TASS, for an incidence of 0.22%. There were two identifiable 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 the cases.[438]

Cataract Surgery Checklist

Protocols to minimize the incidence of preventable surgical errors regarding 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.[439-444] The Wrong-Site Wrong-IOL Checklist (see Appendix 4) is an example of how to document in the surgery chart that the appropriate steps were taken to prevent wrong-site and wrong-surgery events. Adherence to presurgical protocols or checklists has resulted in fewer adverse surgery events and should be implemented.[440,443]

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 resident experience needed to perform cataract surgery. *(III, good quality, strong recommendation)*

In developed countries, phacoemulsification is the preferred method to remove a cataract. The 2010 Leaming Survey highlighted that many respondents use topical anesthesia with intracameral lidocaine, clear-corneal incisions, and a sutureless technique.[445]

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

◆ A secure, watertight incision that minimizes surgically induced astigmatism or reduces pre-existing corneal astigmatism[446-449]
◆ Thorough removal of all nuclear, epinuclear, and cortical material[450]
◆ Negligible or no trauma to the corneal endothelium, iris, and other ocular tissues[451,452]
◆ Preservation of the integrity of the anterior and posterior 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[453]

◆ Use of an OVD to protect the corneal endothelium, manipulate tissues, and maintain adequate working space during surgery[454]

◆ Creation of a capsulorrhexis,[455] which is a continuous curvilinear or femtosecond laser-generated capsulotomy and 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 impedes the development of posterior capsular opacification (PCO) for some IOL designs.[456]

◆ Hydrodissection,[457] which reduces zonular stress during phacoemulsification by mobilizing the nucleus and epinucleus, and facilitating thorough cortical aspiration. Hydrodissection also helps to retard PCO.[458,459]

◆ Nuclear disassembly and emulsification using techniques such as divide and conquer[460] or chopping[461] to allow nuclear removal through a capsulorrhexis and small incision[462]

◆ Thorough removal of remaining epinucleus and cortex[450] (polishing the anterior and posterior capsule when appropriate)

◆ Implantation and centration of a small-incision IOL within the capsular bag, or as dictated by capsular anatomy, secure fixation of the IOL in the ciliary sulcus[463] (with or without sutures or capsulorrhexis capture[464]) or anterior chamber

◆ Removal of OVD to minimize postoperative IOP elevation[465]

◆ Assurance of a watertight incision using sutures or a sealant if the incision size and architecture with adequate stromal hydration alone do not produce a secure, self-sealing wound[328,340,446,466-468]

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.[469-471]

When feasible, small-incision surgery is generally preferred for several reasons.[472] *(I+, good quality, strong recommendation)* Smaller incisions are amenable to self-sealing wound construction so that fewer or no sutures are needed for secure closure. They are therefore inherently safer in the event of sudden patient movement or a suprachoroidal hemorrhage during surgery, and there are fewer physical restrictions postoperatively. They may be associated with less initial postoperative inflammation.[473,474] Finally, smaller incisions induce less unwanted astigmatic change than larger incisions[472,475-479] and result in earlier and greater long-term stability of the refraction.[480-483]

When required, large-incision manual ECCE or manual small-incision cataract surgery (SICS) may be preferred for certain complicated cataract surgeries, such as those with mature nuclei, weak zonules, or a higher risk of corneal decompensation.[484-488]

A recent adjunctive tool used in cataract extraction is a femtosecond laser, [311] which can be used to construct corneal incisions,[489] create arcuate astigmatism correcting incisions,[490-492] perform the anterior capsulotomy, and cleave or soften the nucleus.

Although FLACS is currently gaining popularity, there is still controversy around the relative benefits and disadvantages of the femtosecond laser.[493] Femtosecond laser technology has the potential to improve safety, accuracy, and clinical outcomes. However, FLACS adds cost and new financial and clinical challenges.[494,495] Although the cost can theoretically be passed on to patients under specific insurance exceptions or as a refractive procedure, a financial analysis would be advisable before a practice considers purchasing a femtosecond laser.[495]

Multiple reports document a learning curve when incorporating femtosecond cataract technology into a practice.[496,497] In addition to increasing surgical time, the eye behaves

differently after laser application. Mild increases in inflammation and pupillary constriction may occur.[498,499] Subconjunctival hemorrhage is more common in the immediate postoperative period. Also, there may be certain types of cataracts, such as posterior polar or phacomorphic, for which the femtosecond laser should not be used due to higher complication rates, such as posterior capsular rupture.[500,501] *(II-, moderate quality, strong recommendation)*

The surgeon needs to be aware of many changes necessary in phacoemulsification technique in order to be successful. When dealing with the capsulotomy, the capsule should be pulled centrally to help avoid radial tears.[502] Two clinical studies have shown an increased risk of anterior capsular tear due to the irregular edge created by a femtosecond capsulorrhexis,[502,503] whereas two in vitro studies suggest this may not be a problem.[504,505]

However, more recent FLACS software iterations have minimized irregular edges and outcomes are more predictable.[506,507] During hydrodissection, the air bubbles should be gently decompressed. If performed too aggressively, rapid hydrodissection could lead to a posterior capsular rupture.[508,509] Once nuclear material is extracted, removal of cortical material may be slightly more challenging than with traditional phacoemulsification.

Some peer-reviewed studies provide evidence on the relative benefits of femtosecond laser, specifically for refractive-cataract surgery, and these studies generally tend to demonstrate that FLACS can be a safe procedure comparable to traditional phacoemulsification.[503,510,511]

Several clinical studies indicate that capsulotomies created with a femtosecond laser are significantly more precise in reproducibility than manual continuous curvilinear capsulorrhexis (CCC). This may result in a more stable refractive result with less IOL tilt and decentration compared with manual CCC,[512-517] and it may play a role in both refractive IOL centration and outcomes.

Several studies indicate that less effective phacoemulsification time and cumulative dissipated energy are needed to emulsify the lens following lens fragmentation by the femtosecond laser.[518,519]

Some studies show a small but statistically significant decrease in the outer nuclear layer thickening in subclinical macular edema following FLACS compared with conventional phacoemulsification. However, the clinical significance is not clear.[520,521] In contrast, there is a recent study from Australia that reports a slightly higher trend of cystoid macular edema (CME) in FLACS compared with conventional phacoemulsification that may warrant further study.[522,523]

Although innovative and exciting, femtosecond laser-assisted refractive-cataract surgery offers some surgical and financial challenges. A systematic review found that available evidence could not evaluate equivalence or superiority of this surgery over standard phacoemulsification.[524] In conclusion, there are many nuances, advantages, and disadvantages, and these all need to be reviewed and considered. Femtosecond laser-assisted cataract surgery appears to be a comparably safe and reproducible technology, but further prospective randomized studies are needed to demonstrate the potential clinical utility.

Intraocular Lenses

Intraocular lens implantation is the method of choice to correct aphakia, unless there are specific contraindications.[525] Posterior chamber IOL implantation in the capsular bag is the optimal method in most cases.[526]

Cataract surgeons can choose from a wide variety of posterior chamber IOL styles and materials to find the appropriate lens to match their patients' needs. Intraocular lens optic size, shape, haptic configuration, optic edge design,[527-530] optic and haptic materials,[531-533] and chromophore content are engineered for a variety of characteristics.

Rigid polymethyl methacrylate (PMMA) posterior chamber IOLs were most frequently used before foldable IOLs. Foldable IOLs are now the most common choice following phacoemulsification because they can be implanted through smaller incisions. Foldable IOLs are classified according to their optic material: silicone, hydrophilic acrylic, hydrophobic

acrylic, and collagen/hydroxy ethyl methacrylate [HEMA]-copolymer based. Almost all IOLs have ultraviolet-blocking chromophores. Glistenings are fluid-filled microvacuoles that form within an optic when placed in an aqueous environment. They are observed in many types of IOLs but are most commonly associated with some hydrophobic acrylic IOLs. Recent studies have shown that although glistenings (depending on size) may affect light scatter, they tend not to have an effect on contrast sensitivity or visual acuity.[534-536] Although the impact of glistenings on postoperative visual function and the potential progression of glistenings in the late postoperative period remain controversial, IOL explantation due to glistenings has rarely been necessary.[537] Each IOL is associated with unique positive and negative attributes with regard to material, design, and insertion system. It is therefore incumbent upon each surgeon to have an understanding of the various properties of each IOL.

When combined with a sharp posterior optic edge and an overlapping capsulorrhexis, silicone and hydrophobic acrylic foldable IOLs are associated with a low incidence of PCO in the early years following implantation.[538] All foldable IOL materials are associated with minimal giant-cell foreign-body reaction.[539-541] It may be prudent to avoid implanting hydrophilic acrylic IOLs in patients undergoing concomitant or subsequent endothelial keratoplasty or vitrectomy surgery due to the potential calcification of these lenses upon exposure to intracameral/vitreal air or gas.[542] Foldable IOLs can be inserted with either forceps or with injection devices; in some cases IOLs come preloaded in insertion devices.[543,544] 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.[356]

Noncapsular-bag IOL fixation may at times be necessary due to zonular abnormalities or anterior or posterior capsular tears. The surgeon should have backup IOLs available as a contingency. *(III, good quality, strong recommendation)* Options include implanting either an anterior chamber IOL or a posterior chamber IOL positioned in the ciliary sulcus.[463,545-548] Suturing of posterior chamber IOL haptics to the iris or sclera may be necessary in the absence of sufficient residual capsular support.[463,545-548] Certain unique IOL designs, such as accommodating or plate haptic IOLs, require capsular-bag fixation, and the surgeon should reconsider implantation without proper posterior capsular support and use other forms of fixation or an alternative IOL style. Also, current single-piece acrylic IOLs should not be implanted in the ciliary sulcus because of associated risks, such as IOL decentration and posterior iris chafing, which can cause transillumination defects, pigment dispersion, elevated IOP, recurrent hyphema, and inflammation.[463]

Optimal characteristics of a sulcus-fixated posterior chamber IOL include sufficient overall length, posterior haptic angulation, and the absence of sharp anterior optic edges.[463] With an open posterior capsular barrier, silicone IOLs may compromise surgical visibility should silicone oil or expansile gas ever be required.[549,550] Anticipating a more anterior location of the optic, the sulcus IOL power for the average eye should be decreased by 0.5 D to 1.0 D relative to that calculated for capsular-bag fixation (but decreased less with capsulorrhexis capture of the optic).[551,552] The latter strategy reduces reliance on adequate haptic length to provide optic centration and stability.[553] Because noncapsular bag fixation may increase 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.[554,555] *(III, insufficient quality, discretionary recommendation)*

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.[463,545-548] Risks include improper anatomic placement and suture breakage or knot unraveling.[556-560]

Alternatively, intrascleral fixation of an IOL appears to be an effective and safe technique for IOL fixation when lacking capsular support, and studies have found good positioning of the IOL and insignificant tilt over a relatively short period of time.[561,562] However, long-term studies are lacking.

Effective use of an anterior chamber IOL depends on appropriate IOL design, sizing, and proper placement. Iris deformity, pupil distortion, and physical 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.[463] A peripheral iridectomy should be used to prevent the risk of pupillary block associated with an anterior chamber IOL.[563] *(III, good quality, strong recommendation)* Multiple studies support the efficacy of all three methods of IOL fixation—anterior chamber, iris sutured, and scleral sutured or intrascleral fixation posterior chamber—in the absence of adequate capsular support.[463,545-548]

Optical and Refractive Considerations

Spherical IOLs, in which marginal light rays focus proximally relative to paraxial light rays, have positive spherical aberration.

Aspheric IOLs are designed to reduce or eliminate the spherical aberration of the eye. 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.[282,564-576] However, the potential advantages of aspheric IOLs remain controversial, particularly with respect to functional benefit[577-579] and depth of focus.[144,580] The potential advantages and disadvantages can be affected by pupil size,[581] IOL tilt[582] and decentration,[554] and whether the spherical aberration of the IOL and the patient's cornea are custom matched.[583,584]

Between 15% and 29% of cataract patients have more than 1.5 D of keratometric astigmatism.[585,586] Toric IOLs have been shown to decrease eyeglass dependence compared with nontoric monofocal IOLs.[587,588] In addition, they may offer better predictability and stability of correction compared with incisional astigmatic keratotomy.[589-591]

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.[592] The lenticular contribution to refractive astigmatism will be eliminated with cataract surgery. Toric IOL axis misalignment may reduce the desired refractive effect or may even worsen the overall astigmatism.[593] Because toric IOLs do not correct irregular astigmatism, they should not be used in patients who will require a rigid contact lens.[594] Modified keratometers and aberrometers are available that can be used intraoperatively to help with IOL calculations and toric IOL alignment.[285,595] An effort should be made to determine the true corneal refractive power, which incorporates both the anterior and posterior corneal power. *(III, good quality, strong recommendation)* Lastly, new technology IOLs, such as toric IOLs, have shown good long-term rotational stability.[596]

Use of presbyopia-correcting IOLs or monovision may improve quality of life by reducing eyeglass dependence after cataract surgery.[597] 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 the individual patient's lifestyle and expectations so that the best IOL is selected. Patients should be informed of the potential compromise in quality of vision associated with these choices.[598-600]

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 in-focus eye. 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.[601] 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.[602] 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.[603] Patients with a history of successful adaptation to monovision with eyeglasses or contacts lenses are particularly well suited for this modality.[604,605] Such patients may benefit from distance-corrected eyeglasses for

driving at night. In general, patients with latent strabismus, macular disease, or optic nerve disease make poor candidates for monovision, unless they have previously done well with optical correction.

Presbyopia-correcting IOLs can be classified as multifocal, with near and distance elements in the optic of the lens, or accommodative, whereby the lens changes position or shape within the eye.

Multifocal IOLs achieve their effect by dividing incoming light into two or more focal points and can be classified as refractive or diffractive.[606] A Cochrane systematic review concluded that multifocal IOLs were effective at improving near vision when compared with monofocal IOLs and that unaided distance visual acuity was similar in the two groups.[607] Optical effects of multifocal IOLs may include reduced contrast sensitivity, halos around point sources of light, multiple images, and glare.[608] Whether the improvement in near unaided acuity outweighs the optical side effects of multifocal IOLs will vary among patients, with important factors being the motivation to achieve eyeglass independence and adaptation over time.[609] 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 pathology or latent strabismus. Therefore, the candidacy of patients with amblyopia or abnormalities of the cornea, optic disc (such as glaucoma), and macula for a multifocal IOL must be carefully considered.[600] *(III, insufficient quality, discretionary recommendation)*

Multifocal toric IOLs are currently also available to correct astigmatism concurrently while providing a range of vision. When compared with multifocal IOLs with limbal relaxing incisions, they were found to be more predictable and to have good rotational stability.[610,611]

Multifocal IOLs are available with a lower add for near vision that can help minimize issues of halo and glare.[612,613]

In an attempt to mimic human accommodation, accommodative (with or without a toric component) presbyopia-correcting IOLs are designed to change position or shape in the eye with accommodative effort. These IOLs have demonstrated varied accommodative potential without the loss of contrast sensitivity inherent in multifocal IOLs.[614-617] 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.

Outcomes

Multiple large studies on cataract surgery, including a current Cochrane review, have repeatedly demonstrated favorable outcomes.[618] The 1994 ASCRS National Cataract Database reported that at 3 months postoperatively 86% of all patients had a 20/40 or better BCVA, 57% of patients had 20/25 or better postoperative BCVA, and 75% of patients were within ±1.0 D of target spherical equivalent.[619] With 5788 responses, the mean visual function index score at 3 months postoperatively was 70% compared with 55% preoperatively. (The score is based on a scale of 0 to 100, with 0 indicating inability to perform any of the activities.) The 1999 European Cataract Outcome Study reported that 89% of patients achieved a postoperative visual acuity of 0.5 D or more (20/40 or better), the average induced astigmatism was 0.59 D, and 86% of patients had an induced astigmatism within ±1.0 D.[620] This study was conducted in 14 countries with up to 40 participating surgeons during the years 1995 to 1999, and it collected operative and follow-up information on a total of 8646 patients, including 3033 patients in 1999.

The American Academy of Ophthalmology National Eyecare Outcomes Network (NEON) database (n=7626) also found similar rates of success, with an improvement in visual acuity in 92% of patients and improvement in VF-14 in over 90% of patients.[621] Best-corrected visual acuity of 20/40 or better was achieved by 89% of all NEON patients and by 96% of NEON patients who lacked preoperative ocular comorbid conditions.[621] Seventy-eight percent of patients were within ±1.0 D of target spherical equivalent. Ninety-five percent of patients reported being satisfied with the results of their surgery. Patients

who were dissatisfied with the results of their surgery were slightly older and more likely to have an accompanying ocular comorbidity. More recently, a large multicenter study in the United Kingdom showed results from cataract surgery of 20/40 or better in 95% of eyes with no ocular comorbidity.[622] Several recent papers on clinical outcomes with FLACS report results similar to standard ultrasonic phacoemulsification but with a higher incidence of subconjunctival hemorrhage.[623]

In studies of phacoemulsification cataract surgery performed by ophthalmology residents, the reported range of patients with postoperative BCVA of 20/40 or better was 80% to 91%.[624-629] If eyes with ocular comorbidities are excluded, the reported range of patients with postoperative BCVA of 20/40 or better was 86% to 98%.[627-630] Good predictive results have also been achieved with toric IOLs in resident phacoemulsification cases.[631]

The Cataract Patient Outcomes Research Team (PORT) study identified independent predictors of greater improvement after surgery: younger age (under 65), less comorbidity, higher cataract symptom score, and worse VF-14 (measure of visual function) score.[147] 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.[147,150,632] In another study, 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.[632] However, even patients with diabetes and age-related macular degeneration (AMD) showed significant improvements after cataract surgery, albeit at a lower magnitude than patients without these conditions.[633-637] 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.[638] Even in eyes with 20/20 or better preoperative Snellen acuity, cataract surgery improved patients' self-reported visual impairment.[150] 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 pre- 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.

Complications of Cataract Surgery

Although numerous complications can occur intraoperatively or postoperatively with cataract surgery, those resulting in permanent loss of vision are rare. Major complications are potentially sight-threatening and include infectious endophthalmitis, TASS, intraoperative suprachoroidal hemorrhage, CME, retinal detachment, persistent corneal edema, IOL dislocation, ptosis, corneal decompensation, diplopia, and blindness.

The Cataract PORT reviewed the incidence of cataract complications from studies published prior to 1992 and with an overall phacoemulsification/manual ECCE case mix of 2:1.[639] Six subsequent studies of adverse perioperative outcomes from cataract surgery are summarized in Table 2. In one of these studies, Greenberg et al[640] 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%). The rate of CME was 3% and the rate of retained lens fragments was 2%.

Stein et al[641] 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 period was 0.5%; severe complications were defined as endophthalmitis (0.16%), suprachoroidal hemorrhage (0.06%), and retinal detachment (0.26%). The

probability 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.[642] Of the complications reported, 2% were considered major, including vitreous loss (1%), lens drop (0.1%), iris trauma (1%), retinal detachment (0.2%), and endophthalmitis (0.1%). Other nonmajor complications included wound leak (1%), prolonged corneal edema (0.7%), uveitis (1%), and persistent elevated IOP (0.3%). A 2015 study showed similar results.[643]

Specific complications following cataract surgery are discussed below.

TABLE 2 COMPLICATION RATES FROM SELECTED STUDIES OF CATARACT SURGERY

	Cataract PORT, 1994[639]	Schein et al, 1994[106]	NEON, 2000[621]	Zaidi et al, 2007[642]	Jaycock et al, 2009[622]	Greenberg et al, 2011[640]	Clark et al, 2011[644]
Number of cases	*	717	2603	1000	55,567	45,082	65,060
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
Vitreous loss/ anterior vitrectomy or aspiration	0.8	1.39	1.1	1.1	NA	NA	NA
Iris/ciliary body injury	0.7	0.84	0	1.2	0.55	0.1	NA
Loss of nuclear material into vitreous	NA	0.28	<1	0.1	0.18	0.2	0.16
Suprachoroidal hemorrhage	NA	0.14	0	0	0.07	0	NA
Retrobulbar hemorrhage	NA	0	0	0.1	NA	0	NA
Postoperative (%)				(n=16,731)[∥]			
CME	3.5	3.21	NA	1.2	1.62	3.3	NA
Iris abnormalities	1.3	2.51	NA	NA	0.16	NA	NA
Corneal edema	NA	1.95	<1	0.7	5.18	NA	0.03
Wound leak or rupture	NA	0.84	<1	1.1	0.14	NA	0.06
IOL dislocation, removal, or exchange	1.1	0.28	<1	NA	0.22	0.9	0.19
Endophthalmitis	0.13	0.14	<1	0.1	NA	0.2	0.17
Retinal tear, break, or detachment	0.7	0.14	<1	0.2	NA	0.9	0.37
Visually significant CME	NA	NA	<1	NA	NA	NA	NA
Persistent iritis	NA	NA	1.1	1.1	NA	NA	NA

CME = cystoid macular edema; IOL = intraocular lens; NA = not available; NEON = National Eyecare Outcomes Network; 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, which do not specify whether cataract surgeries are performed by phacoemulsification or manual extracapsular cataract extraction. A survey[645] 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.

Incision complications

An incision that is not watertight can lead to several complications, including postoperative wound leak, hypotony, and endophthalmitis.[336] An incision that is too large will cause leakage of fluid from the wound and destabilize the anterior chamber. 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 60º C or higher.[646] A recent survey identified 419 cases of wound burn, which yielded an incidence of 0.043%.[647] In a multivariate analysis, factors associated with this problem in order of decreasing significance were lower surgical volume, the surgical technique, and the type of OVD used.[647] The risk of wound burn related to an OVD varies among different OVDs.[648] Wound burns can result in wounds that are difficult to close. Surgically induced astigmatism may affect refractive outcomes, particularly with new-technology IOLs.[649]

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 suture tension.[471,650] The induced astigmatism is usually reversed upon suture removal.

Iris complications

Damage to the iris can result from iris prolapse due to conditions such as intraoperative floppy iris syndrome (IFIS)[651,652] or a poorly constructed incision. The 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. Sphincter necrosis may occur perioperatively as a result of endophthalmitis, TASS, or excessively increased IOP.

Corneal complications

Improper instrument entry into the anterior chamber can lead to Descemet membrane tears or detachment.[653,654] 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 an air bubble. 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.[425,437] Prolonged elevated IOP can lead to further endothelial decompensation and corneal edema. The surgeon should avoid working close to the cornea and orient the irrigation port away from the corneal endothelium. *(III, good quality, strong recommendation)* Replenishing dispersive OVD during prolonged phacoemulsification or in the presence of several smaller shards of brunescent cataract can also help protect the corneal endothelium.

Prolonged inflammation

There are several potential etiologies for prolonged postsurgical inflammation. Persistent iritis has been associated with retained lens fragments,[655] previous history of uveitis,[656] and a subacute infection with *Propionibacterium acnes*.[657] 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. The surgeon should ensure proper orientation of IOLs to prevent corneal complications. *(III, good quality, strong recommendation)* Insufficient postoperative anti-inflammatory medication may also be a contributory cause.[658]

Endophthalmitis

According to peer-reviewed literature, the incidence of postcataract surgery endophthalmitis ranges from 0.04% to 0.2% in the United States,[106,318,333,640,659] and from 0.02% to 1.16% elsewhere according to other English-language peer-reviewed literature.[341,349,385,621,639,641,644,660-664] *Staphylococcus epidermidis* is the most common pathogen.[660,661] Risk factors for developing endophthalmitis after cataract surgery include posterior capsular rupture (up to 10-fold increase),[333,336,341,342,664] older age,[341] relative immunodeficiency,[333] resident-performed cataract surgery,[342] wound leak on the first postoperative day,[336] inferior incision location,[333] longer length of surgery,[665] topical anesthesia,[665] and the use of topical lidocaine gel before povidone iodine.[333] The absence of intracameral cefuroxime administration in the European endophthalmitis study was associated with a statistically higher rate of postoperative endophthalmitis.[351]

The type and size of incision (clear corneal or sclera) has been implicated as a possible factor in the development of endophthalmitis.[326] However, several articles found no conclusive evidence for an association of clear corneal incision and endophthalmitis.[333,666,667]

As mentioned earlier in the Infection Prophylaxis section, two pharmacologic interventions have been shown to reduce the rate of postoperative endophthalmitis in prospective randomized clinical trials. They include preparing 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. [351,368,369,393,668-671] The lack of a commercially available single-dose preparation is the reason quoted most often for not using cefuroxime.[417,672] Some surgeons prefer moxifloxacin to cefuroxime, but definitive prospective clinical trials are lacking for patients undergoing phacoemulsification.[400,673,674] However, one recent large retrospective study showed the two to be equally effective.[346] A prospective study that was performed in India found a statistically significant reduction in endophthalmitis in a cohort of patients who received intracameral moxifloxacin compared with a control group that did not receive it, but the surgical techniques were considerably different between the two groups.[675,676] As an additional consideration, bacterial resistance to moxifloxacin is quite different in India and the United States. Financial cost and fear of TASS are often cited as the primary reasons for not using intracameral antibiotics.[677,678]

Patients who develop endophthalmitis may present with complaints of decreased vision, pain, redness, new floaters, and eyelid edema.[679,680] Although historically the onset of symptoms was considered to occur during the first postoperative week,[681-683] newer studies report a delayed onset of up to 13 days.[333,684] Patients should be encouraged to call surgeons postoperatively. It is important to minimize any communication barrier between patient and surgeon. Common postoperative findings include conjunctival injection, corneal edema, anterior chamber inflammation, hypopyon, and vitritis.[679,680] Endophthalmitis must be differentiated from TASS, which has a slightly different time course and requires a completely different treatment.

If endophthalmitis is suspected, referral to a retina specialist is appropriate. If a retina specialist is not available within 24 hours, the anterior or posterior segment should be tapped for evaluation of possible pathogens, followed by an intravitreal injection of antibiotics.[681] *(I-, good quality, strong recommendation)* The Endophthalmitis Vitrectomy Study (EVS) recommended an intravitreal tap plus injection of antibiotics in patients who presented with vision of hand motion or better. Conversely, patients who presented with vision of light perception or worse were more successfully treated by means of pars plana vitrectomy and antibiotics.[681]

Posterior capsular tear or zonular rupture

Reported rates of posterior capsular or zonular ruptures range from 2% in uncomplicated cases up to 9% in high-risk patients who underwent pars plana vitrectomy.[621,622,685-687] Risk factors for posterior capsular tears and 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 (systemic tamsulosin) antagonist medication, previous trauma, inability of the patient to lie flat, and resident-performed cataract surgery.[688,689] Early adopters of femtosecond lasers for lens fragmentation experienced a higher rate of capsular rupture.[508] However, recent reports have not confirmed these higher rates. Intraoperative risk factors include loose zonules, need for capsular stain, and miosis.[689]

The factors listed above are the known risk factors. However, posterior capsular and zonular complications may occur without any obvious predisposing factors. A discussion with the patient about possible complications and difficulty in assessing risk before cataract surgery may be beneficial.

Retained lens fragments

The incidence of retained lens fragments is 0.18% to 0.28%.[622,639] If there is vitreous loss with posteriorly dislocated lens fragments, the surgeon should perform an anterior vitrectomy and implant an IOL with an appropriate size and design.[690] *(III, good quality, strong recommendation)* The use of injected triamcinolone may aid in visualization of residual vitreous.[691] Because of the increased risk of inflammation and elevated IOP, strong consideration should be given to referring patients who have retained nuclear lens fragments to a retina surgeon during the early postoperative period.[692] Small amounts of cortex can usually be watched. One study found that IOLs placed during primary surgery complicated by vitreous loss required subsequent explantation in a large number of cases. If the proper backup-IOL power, size, or design is unavailable, then the surgeon should consider leaving the eye aphakic at the time of the primary surgery.[693] Corneal decompensation is a significant risk when lens fragments are retained in the anterior chamber.[694]

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.[695-697] *(III, good quality, strong recommendation)*

Retinal detachment

Overall rates of retinal detachment range from 0.26% to 4%.[641,644,667,698-703] Risk factors for development of retinal detachment after cataract surgery include axial length more than 23 mm (especially high myopia), posterior capsule tear, vitreous loss, younger age, male gender, lattice degeneration, zonular dehiscence, retinal detachment in the fellow eye, and the new onset of a postoperative posterior vitreous detachment.[667,698-703] In one study, the mean interval between cataract surgery and retinal detachment was 39 months,[703] but the increased risk of retinal detachment in pseudophakic eyes may continue for as long as 20 years.[704] In a single-surgeon prospective case series of 22 years' duration, the risk of retinal detachment after phacoemulsification for female patients with axial length less than 24 mm and age 60 or younger was extremely low.[705] There was no statistically significant difference in the probability of retinal detachment after ECCE compared with phacoemulsification.[704]

Suprachoroidal hemorrhage

Historically, the incidence of suprachoroidal hemorrhage related to large-incision cataract surgery was reported to be 0.15% to 0.19% and associated with myopia, glaucoma, diabetes, atherosclerotic vascular diseases, hypertension, and prolonged intraoperative hypotony.[706] Published data on the incidence of suprachoroidal hemorrhage following phacoemulsification are lacking. The risk is probably lower because the surgical duration is shorter. The majority of published studies support the continuation of anticoagulant and antiplatelet therapy during cataract surgery when performed by a skilled surgeon.[707] *(I-, good quality, strong recommendation)* Anticoagulation with warfarin does not significantly increase the frequency of choroidal hemorrhage, but exposure to warfarin would likely worsen the severity of a hemorrhage once started.[708]

Clinical signs and symptoms of an intraoperative choroidal hemorrhage include sudden pain, scotoma and loss of red reflex, elevated IOP, shallowing of the anterior chamber, and

iris prolapse.[709] Failure to diagnose a hemorrhage and secure the incision promptly can increase the likelihood of sight-threatening complications.

Cystoid macular edema

Clinically significant CME occurs infrequently after routine uncomplicated SICS (1%–3%)[622,640,642] and often responds well to topical anti-inflammatory medication; however, recalcitrant cases may be associated with permanent impairment of central visual acuity. Risk factors for CME include previous uveitis, posterior capsule rupture with vitreous loss, retained lens material, diabetic retinopathy, venous occlusive disease, epiretinal membrane, prior vitreoretinal surgery, nanophthalmos, retinitis pigmentosa, radiation retinopathy, male gender, older age, and a history of pseudophakic CME in the fellow eye.[710] 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 CME as well as to treat established CME. There is evidence that NSAIDs, alone or in combination with topical corticosteroids, decrease the likelihood of postoperative CME. There are studies showing benefit to early visual recovery but no level I evidence yet demonstrating a long-term benefit (i.e., 3 months or more).[395,711-728]

The use of intravitreal anti-angiogenesis agents at the time of cataract surgery for prophylaxis or treatment for select cases of CME is being investigated.[729] In one case-control study, eyes with diabetic macular edema (DME) were randomized to receive intravitreal bevacizumab. Injections at 1 and 3 months after surgery showed a significant decrease in retinal thickness compared with a control group.[730] 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.[731]

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 prevention of CME has been advocated for high-risk eyes based on a number of studies.[710,732] Administration of NSAIDs before and immediately after surgery may hasten the recovery of vision in the first few weeks following surgery. However, there is no level I evidence that visual outcome is improved by the routine use of prophylactic NSAIDs at 3 months or more after cataract surgery.[725] *(II+, moderate quality, strong recommendation)* Anti-vascular endothelial growth factors and intravitreal corticosteroids may be useful, especially in diabetics, when topical medications fail or produce limited results.[733,734]

Intraocular pressure

Many eyes may have a recognized tendency for transient elevation of IOP during the early postoperative period. Although this rarely causes permanent injury, acute postoperative IOP elevation can induce pain, microcystic corneal edema, and nausea. Some eyes may be more susceptible to optic nerve damage or retinal vascular occlusion. The likelihood for IOP elevation increases if excess amounts of the OVD remain in the eye at the conclusion of surgery. Thorough removal of OVD is recommended, since residual OVD remaining in the eye is a likely cause of IOP elevation.[735] Dispersive OVDs are more likely than cohesive OVDs to be retained in the eye because they adhere to intraocular structures such as the cornea, iris, and IOL. The optimal pharmacological regimen for preventing an immediate postoperative IOP spike is unclear. It appears that topical aqueous suppressants and intracameral carbachol are beneficial.[736-754] Topical corticosteroid use may elevate IOP in eyes that are "steroid responders."[755] 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.[756-758] Corticosteroid cessation usually results in a reduction of the IOP to

normal levels, and the IOP should be monitored in patients treated with postoperative corticosteroid medication.[755] *(II-, good quality, strong recommendation)*

Complications of Intraocular Lenses

Complications specific to the IOL occur infrequently but vary depending on the design and material of the particular IOL. In the ASCRS/ESCRS registry, the most common reasons for explantation of foldable IOLs include dislocation or decentration, glare or optical aberrations, incorrect power, and opacification.[759] Multifocal implants, in particular, are most often explanted because of "waxy" vision (patient-described vision as though looking through wax paper), glare, halos, other dysphotopsias, and blurred vision that cannot be corrected optically.[760] Intraocular lenses may also be damaged during implantation, and intraoperative lens exchange may be necessary.

Posterior chamber IOL decentration can result from damaged haptics, zonular dialysis, anterior or posterior capsular tears, asymmetric capsulorrhexis, asymmetric capsular contraction and fibrosis, and asymmetric placement of the haptics with one in the ciliary sulcus and the other in the capsular bag. A malpositioned posterior chamber IOL can cause significant visual complaints, including edge glare, higher-order aberrations, or IOL inflammation associated with uveal irritation, such as iris chafing. Iris chafing and secondary glaucoma is common with malpositioned single-piece acrylic IOLs and any lens that is placed upside down.[463]

Dislocation and decentration have been reported with virtually all IOL materials and models, including both one- and three-piece designs.[759] This complication is seen most commonly when IOLs are not placed symmetrically within the capsular bag or when an IOL is placed without an intact capsulorrhexis. The major predisposing factors for IOL subluxation in one study were secondary implantation, posterior capsular rupture, and mature cataracts.[761] Plate haptic silicone IOLs can dislocate posteriorly following neodymium: yttrium-aluminum-garnet (Nd:YAG) laser capsulotomy and, rarely, spontaneously from capsular contraction.[762] The problem usually occurs many years after surgery and may happen even if large fixation holes are present on the haptics.[763] Delayed in-the-bag spontaneous posterior IOL dislocation is associated with zonular insufficiency, such as with pseudoexfoliation (exfoliation syndrome), prior vitreoretinal surgery, or a history of trauma.[764-766] The onset was delayed and occurred on an average of 8.5 years following uncomplicated cataract surgery in a study of 86 consecutive cases.[766] Spontaneous bag-IOL dislocation can occur with all IOL materials, including PMMA, silicone, and hydrophobic acrylic, as well as with both one-piece and three-piece IOL designs.[766] There is no evidence that the implantation of a capsule tension ring reduces the risk of late dislocation of the capsular bag.[767,768]

Glare or optical aberrations are a common reason for lens explantation. The term *dysphotopsia* has been used to describe a variety of unwanted visual phenomena encountered by pseudophakic patients.[769,770] Positive dysphotopsias may include halos, ghost images, starbursts, and arcs, rings, or flashes of light that may ultimately interfere with visual function. The most common negative dysphotopsia is manifested as a dark crescent or curved shadow that can appear similar to a scotoma or "horse blinder" in the peripheral temporal field of vision.[771-773] Initially, positive and negative 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.[528,774-777] 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.[771,775,778,779] A large gap between the posterior iris and the anterior lens surface appears to increase the incidence of temporal shadows.[780] Complications such as IOL opacification, cracked or damaged optics, and IOL decentration may also cause dysphotopsias.

Dysphotopsias decline in prevalence and severity with the passage of time. In one study, the incidence of negative dysphotopsias was 15% on the first postoperative day, whereas 1 year after surgery, with no intervention, 3% of patients reported negative dysphotopsias.[773]

Implantation of a piggyback IOL or reverse optic capture (placing the optic anterior to the capsulorrhexis) appears to reduce the symptoms of negative dysphotopsia.[781] 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.[782] Negative dysphotopsia may also be induced at the interface of the capsulorrhexis and the anterior surface of the IOL, suggesting that a shadow of the anterior capsulotomy edge is projected onto the nasal peripheral retina.[781]

Incorrect IOL power may lead to explantation in some cases. It is not possible to predict precisely the final axial position of an implanted IOL. An unwanted refractive result or "surprise" is therefore possible. The risk is greater with inaccurate keratometry or axial length measurements, which may occur with uncooperative patients, postrefractive surgery eyes, and atypical anatomic variations such as a staphyloma (see Biometry and Intraocular Lens Power Calculation section and sections that discuss cataract surgery following prior keratorefractive surgery). Incorrect IOL labeling or mistakenly implanting the wrong IOL may result in an unwanted refractive surprise. Finally, surgical factors that can affect the effective lens position include retained OVD in the bag, capsular block, improper haptic or optic placement, capsulorrhexis diameter, and inversion of the IOL.

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. *(III, good quality, strong recommendation)* Surgical alternatives to IOL exchange include keratorefractive surgery and secondary ciliary sulcus implantation of a piggyback IOL.

The incidence of IOL opacification or calcification appears to be decreasing according to the most recent survey of IOL explantation.[759] Although IOL calcification was reported with earlier hydrophilic acrylic IOLs, newer hydrophilic acrylic IOLs have been used widely in Europe with a minimal incidence of calcification.[783-787] Opacification of hydrophilic acrylic IOLs may be misdiagnosed as a clouding of the lens capsule or vitreous, leading to unnecessary surgical intervention.[788] Opacification of silicone IOL optics due to calcium deposits following Nd:YAG laser capsulotomy in eyes with asteroid hyalosis has been reported.[789,790] For this reason, it may be prudent to avoid silicone IOL implantation in these patients. Occasionally, IOLs must be explanted because of intolerable glistenings.[537]

The complication of interpseudophakic opacification can occur when lens epithelial cells migrate in between the optics of two piggybacked IOLs (especially two hydrophobic acrylic IOLs) that have both been implanted within the capsular bag.[265,266] This dense fibrocellular material is difficult to remove and may require explantation of both IOLs.

This problem has not been reported when a silicone piggyback IOL is implanted in the ciliary sulcus following bag placement of the initial acrylic IOL, unlike when both IOLs are placed within the capsular bag.

As noted earlier, implantation of single-piece acrylic IOLs in the ciliary sulcus is associated with pigment dispersion, iris transillumination defects, elevated IOP, and recurrent inflammation or hemorrhage.[463] Malpositioned anterior chamber IOLs may result from improper sizing, iris tuck following implantation, or rotation of a haptic through a peripheral iridectomy. Excessive anterior chamber IOL mobility can lead to corneal endothelial decompensation.

Some complications of foldable IOLs are unique to a specific type of material or lens design. For instance, mixing a blue-light filtering IOL in one eye with a clear IOL in the other may result in a perceived color difference.[791] Hydrophilic acrylic IOLs may calcify if subsequent air or gas tamponade is necessary, such as in Descemet stripping endothelial keratoplasty (DSEK) or Descemet membrane endothelial keratoplasty (DMEK).[542,792-794] In eyes at risk for corneal endothelial decompensation, it is prudent to choose another lens material. Silicone oil adheres to IOLs made from silicone more than to lenses made from other materials.[795] As a result, it is best to avoid implanting silicone lenses in any eye at risk for subsequent silicone oil injection.[796] 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 it contracts aggressively following surgery.[797-799] Anterior capsule polishing and capsule tension ring implantation may reduce the incidence of this problem. Finally, toric IOLs may rotate shortly after implantation. Silicone plate-haptic toric lenses with a short overall dimension had a high initial rate of postoperative malpositions, but subsequent lengthening of the haptic dimension on lower-power models largely solved this problem.[800] Late rotations of plate-haptic lenses are simply not seen.[801] Single-piece acrylic IOLs are more rotationally stable at the time of implantation, although malpositions are seen occasionally.[802] 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 misalignment.[803] Reoperation to reorient a toric optic on axis usually remedies this problem.[804]

Ocular Comorbidities

Preoperative ocular comorbidities may adversely affect the outcome of cataract surgery.[632,805,806] Many comorbid conditions are associated with the potential for reduced improvement in visual function or BCVA,[807-809] and the patient should be informed and counseled prior to surgery. *(III, good quality, strong recommendation)* This is particularly true if the patient is electing to receive a refractive- or presbyopia-correcting IOL. Comorbid conditions found in patients with cataracts and the special considerations associated with these conditions are listed in Table 3.

TABLE 3   SELECTED OCULAR COMORBIDITIES

Comorbidity	Special Considerations (aside from reduced visual potential)
Amblyopia	• Reduced visual potential
Age-related macular degeneration[810-812]	• Reduced visual potential • Unrecognized preoperative exudative disease
Diabetic retinopathy[813-817]	• Unrecognized retinopathy • Progression of existing retinopathy • CSME • Poorly dilating postoperative pupil • Neovascularization of the iris, neovascularization of the angle, and neovascular glaucoma
Epiretinal membrane[710,818]	• Reduced visual potential • CME
Fuchs corneal endothelial dystrophy[819]	• Reduced visualization during surgery • Prolonged postoperative corneal edema • Pseudophakic bullous keratopathy • Reduced visual potential
Glaucoma[820-825]	• Elevated postoperative IOP • Reduced function of prior filtering surgery
Pseudoexfoliation (exfoliation syndrome)[826-832]	• 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
Retinopathy of prematurity[833]	• Amblyopia • Intraoperative miosis • Traction retinal detachment • Loose zonules

TABLE 3   SELECTED OCULAR COMORBIDITIES (CONTINUED)

Comorbidity	Special Considerations (aside from reduced visual potential)
Strabismus	• Amblyopia • Postoperative diplopia
Uveitis[834-839]	• Posterior synechiae • Weakened zonules • Protein and cellular deposits on the lens implant • CME • Secondary glaucoma • Prolonged postoperative inflammation

CME = cystoid macular edema; CSME = clinically significant macular edema; IOL = intraocular lens; IOP = intraocular pressure; PCO = posterior capsule opacification

The presence and extent of AMD may be defined preoperatively through the use of diagnostic instrumentation such as OCT, fluorescein angiography, and potential acuity instruments, which can assist in establishing realistic expectations. There is increasing evidence that the risk for worsening of pre-existing AMD following cataract surgery is unlikely when compared with natural history.[840-843]

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.[730,731,844-849] Studies of uncomplicated phacoemulsification do not show the significantly increased risk for progression of diabetic retinopathy reported after ECCE and ICCE.[850] Cataract surgery does not appear to increase the risk of progression of adequately treated proliferative diabetic retinopathy or macular edema.[813,851] However, patients with pre-existing DME or more severe retinopathy are at increased risk for the development or progression of DME after cataract surgery.[710,850]

Because of the risk of corneal decompensation in the presence of corneal endotheliopathy, the surgeon may consider using retentive OVDs along with optimizing machine parameters and surgical techniques that reduce cumulative ultrasound time and endothelial trauma.[852,853] When selecting the IOL power, the potential hyperopic shift with endothelial replacement surgery should be considered.[854]

Pseudoexfoliation (exfoliation syndrome) is commonly associated with a small pupil and weak zonules, which increases the risk of capsular rupture and retained nuclear fragments.[830] A preoperative anterior chamber depth from the ocular surface of less than 2.5 mm is indicative of zonular weakness and increases the risk of complications almost fivefold.[826] Because of the risk of late bag-IOL dislocation in these patients, larger capsulorrhexis, capsule polishing, and Nd:YAG laser anterior capsule relaxing incisions may be considered to prevent or treat anterior capsule contraction.[766,767,855]

The optimal timing of cataract surgery in the presence of uveitis is a function of many factors.[856,857] Inflammation should be inactive or at its best level of control possible, generally for 3 or more months prior to elective surgery.[838,858,859] Topical and/or periocular, intraocular, and systemic anti-inflammatory medications should be started prior to surgery. *(III, good quality, strong recommendation)* They are then used more frequently and for longer durations following surgery. Intravitreal, periocular, or systemic administration of anti-inflammatory medication may also be considered.[860]

In addition to ocular comorbidities, other characteristics of the patient or eye may be associated with a higher risk for intraoperative and postoperative complications. High-risk characteristics include a history of previous eye surgery, special types of cataracts, very large and very small eyes, deeply set eyes, small pupils or posterior synechiae, scarred or cloudy corneas, weak or absent zonules, prior ocular trauma, and the systemic use of alpha-1a antagonists. Each set of circumstances poses unique challenges (see Table 4). As with

ocular comorbidities, patients with high-risk 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 in the event that complications occur. *(III, good quality, strong recommendation)*

TABLE 4   HIGH-RISK CHARACTERISTICS FOR INTRAOPERATIVE AND POSTOPERATIVE COMPLICATIONS

High-Risk Characteristic	Special Considerations
Anterior megalopia	• Zonular laxity • Pigment dispersion (associated with elevated IOP) • Retinal detachment
Contour abnormalities	• Keratoconus • Pseudoexfoliation • Short eye (i.e., hyperopia)
Corneal opacification	• Reduced visibility • Worsening of corneal clarity
Deeply set eye, narrow lid fissure, or prominent brow	• Reduced visibility • Poor access to the limbus • Pooling of irrigation fluid • Wound deformation and leakage
Dense brunescent nuclear cataract[861,862]	• 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[863-865] (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)
High myopia[866-871]	• Anterior chamber depth fluctuation due to reverse pupillary block • Difficulty calculating lens implant power, especially with posterior staphyloma • Decreased ocular rigidity, difficulty sealing the wound • Increased risk of retinal detachment
Miotic pupil[689,872]	• Poor visualization • Increased risk for capsule tear/vitreous prolapse • Increased risk for iris damage and prolapse
Posterior polar cataract[873,874]	• 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[875]	• Silicone IOLs may compromise subsequent surgical visibility if posterior segment surgery or silicone oil is needed
Prior anti-VEGF injections	• Endophthalmitis • Posterior capsular rupture • Retained lens fragments[876]

TABLE 4   HIGH-RISK CHARACTERISTICS FOR INTRAOPERATIVE AND POSTOPERATIVE COMPLICATIONS
(CONTINUED)

High-Risk Characteristic	Special Considerations
Prior glaucoma filtration surgery[877-880]	• Increased filtration through the bleb during surgery • Decreased filtration or bleb failure after surgery • Postoperative hypotony • Zonular laxity
Prior keratorefractive surgery[881-883]	• 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 pars plana vitrectomy[884-886]	• 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 zonules
Prior keratoplasty[887-889]	• Poor visualization • Graft rejection or failure • IOL-power calculation inaccuracy • Hyperopic shift in association with DSEK
Prior scleral buckling surgery[890,891]	• Change in axial length affects IOL power calculation • Conjunctival scarring • Increased risk of sclera perforation with injection anesthesia
Pseudoexfoliation	• Zonular laxity • Poor pupil dilation • Elevated IOP after surgery
Relative anterior microphthalmos[892,893]	• Damage to iris, cornea, and posterior capsule • IOL-power calculation inaccuracy
Shallow anterior chamber	• Iris injury • Iris prolapse • Postoperative corneal edema
Use of systemic sympathetic alpha-1a antagonist medication for treatment of prostatic hypertrophy[894,895] and other systemic conditions	• Poor pupillary dilation, intraoperative miosis, iris billowing and prolapse
White cataract (mature cortical cataract)[896-899]	• Difficulty performing the capsulorrhexis (capsule staining may be helpful)[900] • Lens intumescence • Radial capsulorrhexis tear with extension into posterior capsule
Zonular laxity or dehiscence (e.g., trauma)[689,901,902]	• 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

DSEK = Descemet stripping endothelial keratoplasty; IOL = intraocular lens; IOP = intraocular pressure; VEGF = vascular endothelial growth factor

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.[903] A specific OVD may be selected based on its characteristics in cases of corneal endothelial deficiency, shallow anterior chamber, intumescent cataract, and small pupil.[903]

Capsular dyes to stain the anterior capsule may be considered in cases of a white or mature cataract, or where visibility is compromised.[897,900]

Capsular tension rings can be useful adjunctive devices when weak zonules are present, reducing the likelihood of intraoperative zonular separation and capsular complication,[904] and they may improve postoperative IOL centration.[905] In cases of more profound zonulopathy, other options include capsular retractors, a modified capsular tension ring, or a capsular tension segment for scleral suture fixation.[906]

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.[907] Mechanical methods include viscomydriasis, release of posterior synechiae, pupil stretching, or microsphincterotomies, iris retractors, or pupil expansion rings.[908]

Intraoperative floppy iris syndrome is a unique small-pupil syndrome associated with iris billowing and prolapse as well as with progressive intraoperative miosis.[894,909] It is associated with a higher rate of surgical complications, particularly when it is not recognized or anticipated.[894,909-912] It can be anticipated when the patient has a history of using oral alpha-1 antagonists (e.g., tamsulosin). 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.[894,909,910] *(II-, moderate quality, strong recommendation)*

Systemic Comorbidities

Systemic comorbidities that may be of importance intraoperatively include diabetes mellitus, pulmonary dysfunction, cardiovascular dysfunction (e.g., poorly controlled blood pressure, poorly controlled heart failure), musculoskeletal disorders causing positional difficulties, tremor, severe hearing impairment, anxiety disorders, mental retardation, dementia, and coagulopathies.[913] 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. *(III, good quality, strong recommendation)*

The occurrence of IFIS is strongly associated with systemic alpha-1 antagonists, whose most common indication is the symptomatic treatment of benign prostatic hyperplasia.[894,895,909,914] The American Urological Association guidelines for the management of benign prostatic hyperplasia recommend that men and women with planned cataract surgery avoid the initiation of alpha-1 antagonists until their cataract surgery is completed.[915] Discontinuing alpha-1 antagonists preoperatively does not typically prevent IFIS, which may occur long after drug cessation.[894,909-911,915] Several retrospective and prospective studies[894,909,911,912,916] suggest that IFIS is more frequent and severe in patients taking the alpha-1a subtype-specific antagonist, tamsulosin, than in patients taking nonselective alpha-1 antagonists,[917] and this has been confirmed in a meta-analysis.[918] Intraoperative floppy iris syndrome is associated with a higher risk of complications.[651]

A 2009 meta-analysis found that patients taking warfarin while undergoing cataract surgery had a threefold increase (overall 9%–10% incidence) of bleeding events compared to those not on warfarin.[919] The vast majority of bleeding events were self-limited, typically hyphemae 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, or peri- 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).[708] 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.

Another study of 19,283 surgeries (74% of which included a peri- 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.[920]

Data on the use of newer anticoagulants with cataract surgery are sparse. One study randomized patients with atrial fibrillation to either warfarin or dabigatran, with temporary cessation before surgery, and found similar rates of periprocedural bleeding.[921]

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.[922] 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.[708]

In summary, several studies show a higher incidence of subconjunctival hemorrhage in patients undergoing cataract surgery while taking antiplatelet or anticoagulant medication,[708,919,923,924] but the available data do not show an increase in sight-threatening complications[708,920,923,924] or decreased postoperative visual acuity.[919] While reassuring, given the very low rate of ocular hemorrhagic complications of cataract surgery, these data are still limited by insufficient power to definitively conclude that anticoagulation does not increase the risk for ocular hemorrhagic complications from local anesthesia or operative hemorrhage. Evidence-based guidelines recommend continuation of anticoagulants in patients undergoing cataract surgery provided that the international normalized ratio is in the therapeutic range[925-927] *(I+, good quality, strong recommendation)* and that aspirin be discontinued perioperatively only if the risk of bleeding outweighs its potential benefit.[928] *(I-, good quality, strong recommendation)* Management of these cases should still be tailored to the individual patient's situation.[929,930]

There are no recommendations from either the American Heart Association[931] 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.[932]

Combined Surgery and Special Circumstances

Cataract surgery and glaucoma

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, and endocyclophotocoagulation.[933] A Veterans Affairs retrospective cohort study has shown 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.[934]

Cataract surgery with IOL implantation alone results in a modest reduction of IOP, which may be particularly advantageous for patients with suspected or confirmed primary angle

closure or for mild to moderately severe open-angle glaucoma controlled on medication.[935] 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.[820,822,824,936,937] A more recent prospective study found older patients, eyes with shorter axial length, women, and those with glaucoma or pseudoexfoliation more likely to benefit from this effect.[938] Moreover, an assessment by the American Academy of Ophthalmology and a review by Allen presented similar findings.[618,939]

Generally, a combined phacotrabeculectomy is not as effective as glaucoma surgery alone in lowering IOP.[935,940] Both one-site and two-site combined procedures appear to provide similar IOP reduction.[941] Phacoemulsification combined with trabeculectomy provides good IOP control as well as improved BCVA compared with preoperative vision.[942,943] A variety of new glaucoma technologies may be combined with cataract surgery. These include canaloplasty,[944] ab interno trabeculotomy,[945] endocyclophotocoagulation,[946] and ab interno trabecular bypass microstents[947] 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 the IOP as much.[948,949] A prospective, multicenter, randomized, single-masked, controlled clinical trial showed that IOP was clinically and statistically significantly 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.[950]

Potential benefits of a combined procedure (cataract extraction with IOL implantation and trabeculectomy) are protection against a potential postoperative IOP spike and long-term IOP control with a single operation.[935] However, a 2015 Cochrane review examined combined versus cataract surgery alone in patients with glaucoma and concluded that there is low-quality evidence that combined cataract and glaucoma surgery may result in better IOP control at 1 year compared with cataract surgery alone. The authors suggested the need for further RCTs to further develop evidence-based therapeutic guidelines.[951]

Although filtration surgery is potentially indicated in eyes with active uveitis, neovascularization, or multiple anterior segment problems, there are disadvantages to performing it as a separate procedure before cataract surgery. These include increased perioperative and anesthetic risks and the possibility of inducing filtration failure as a result of subsequent cataract surgery.

The benefit of the adjunctive use of antifibrotic agents (mitomycin-C and 5-fluorouracil) to reduce the potential for bleb failure in combined phacotrabeculectomy remains controversial. A 2014 Cochrane review found no RCTs to test the effectiveness of antimetabolites with the goal of preventing previous trabeculectomy failure and concluded with the need for such trials in the future.[952] Although it appears that commonly-used mitomycin-C may be effective in producing lower IOPs long-term when used with combined procedures, 5-fluorouracil has no such effect.[935,940,953] Potential vision-threatening complications, such as bleb-related endophthalmitis,[954-956] hypotony maculopathy,[957] and late-onset bleb leaks[958] should be considered in the decision to use antifibrotic agents.

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.

Cataract surgery and keratoplasty

The presence of endothelial dystrophy presents a challenge to the cataract surgeon in predicting how well the compromised cornea will function following cataract surgery. Evaluation of the corneal endothelium is helpful in assessing the cataract patient preoperatively. If a slit-lamp biomicroscopic examination reveals microcystic edema or stromal thickening, and/or central corneal pachymetry greater than 640 microns,[852] and/or low central endothelial cell counts by specular microscopy, there is an increased likelihood of corneal failure following cataract surgery. A history of prolonged blurred vision upon awakening in the morning often indicates significant endothelial pump impairment. If the

lack of evaporation while sleeping leads to symptomatic corneal edema, then the likelihood of decompensation after cataract surgery is high. Under these circumstances, a combined procedure of cataract extraction, IOL implantation, and corneal transplantation may be considered.[959] With borderline endothelial reserve, a more peripheral incision, either temporal clear cornea or corneoscleral, and repeated instillation of OVD may preserve more endothelial cells.[960]

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

◆ Cataracts may progress more rapidly after corneal transplantation
◆ The use of topical corticosteroids following surgery may hasten PSC development
◆ Cataract surgery subsequent to corneal transplantation may damage the corneal graft
◆ Surgery is limited to a single procedure
◆ Visual rehabilitation is more rapid

The use of capsule staining dyes may improve the likelihood of achieving an intact capsulorrhexis when performing a combined corneal transplant and cataract extraction.[961]

Because the postpenetrating keratoplasty corneal curvature is not known at the time of a combined procedure, IOL calculations are less accurate.[962] Therefore, some surgeons prefer to perform penetrating keratoplasty first, followed by cataract removal later after sutures are out and the corneal graft contour has stabilized. If the cataract is removed following suture removal and stabilization of corneal graft keratometry, a more predictable IOL power and, hence, refractive result may be possible.[963,964] In some cases, this approach has the advantage of reducing the amount of "open-sky" time during the penetrating keratoplasty surgery. These considerations apply to deep anterior lamellar keratoplasty as well. If possible, at the time of surgery, phacoemulsification should be performed before penetrating keratoplasty if visualization is adequate in order to limit the amount of open-sky time.[965] *(III, good quality, strong recommendation)* However, hydration of the vitreous and high posterior pressure is a potential problem during the keratoplasty phase.

An alternative to penetrating keratoplasty for the treatment of endothelial decompensation is transplantation of the endothelium and posterior stroma or replacement of the endothelial layer with Descemet membrane alone.[966,967] These procedures can be combined with phacoemulsification and foldable IOL implantation with good results.[854,968] Among other potential advantages, this approach preserves the anterior corneal curvature and, therefore, should improve IOL-power predictability when compared with combined penetrating keratoplasty and cataract surgery. Both OCT and Scheimpflug imaging have shown Descemet stripping endothelial keratoplasty to induce a hyperopic refractive shift due to the change in the posterior corneal contour. Although it decreases over time, the hyperopic shift (approximately +0.6 D after 12 months in one study[969] and +1.47 D from the expected biometry result in a second study[970]) should be considered if there is significant risk of corneal decompensation following cataract surgery.[969,970]

Unfortunately, studies to date have shown variability in hyperopic shift. One showed a mean decreased corneal power of 1.94 D compared with controls,[971] while another reported a mean outcome of +1.63 D from the expected result looking at combined corneal and cataract surgery (range of 0 D to 4.0 D).[972] A third showed only a 0.15 D hyperopic shift that was not statistically different from the preoperative refraction.[973] This variability depends on how the posterior corneal transplant is fashioned, so it is best to check with the corneal surgeon to determine the expected result and adjust the IOL power accordingly. The refractive shift will be less of a problem with DMEK, where a reported hyperopic shift was 0.49 D (range from -1.00 D to +1.50 D).[974] A retrospective case review on the management of postkeratoplasty astigmatism showed that toric IOLs placed during cataract surgery, after penetrating keratoplasty and full suture removal, reduced manifest refraction cylinder and that uncorrected distance visual acuity and corrected distance visual acuity improved in patients with moderate to high regular preoperative topographic astigmatism.[188]

If the indication for considering corneal transplantation is the presence of a central opacity, rather than endothelial dysfunction, and adequate clear cornea is present in the midperiphery, the surgeon has the option of performing cataract surgery followed by a sphincterotomy to establish a clear entrance pupil.[975] The use of a capsule-staining dye can facilitate the ability to perform cataract surgery safely in the presence of a mild corneal opacity, possibly avoiding the need for corneal transplantation when the principal indication for a corneal transplant is to improve surgical visualization.[976]

Cataract surgery and vitreoretinal surgery

Cataract surgery is often necessary before, during, or following vitreoretinal surgery. Vitreoretinal procedures, including intravitreal injections, may cause pre-existing cataracts to progress, typically manifesting as increased nuclear sclerosis.[977-982] Management of such cataracts may be more complex, because capsular defects or weakened zonules may be present. 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. Combined vitreoretinal and cataract surgery offers the advantage of a single operative procedure and anesthesia, potentially faster recovery, and cost-effectiveness.[983-985] A wide range of vitreoretinal disorders may be dealt with concomitantly, including vitreous hemorrhage, diabetic retinopathy, epiretinal membrane, macular hole, and retinal detachment.[986-988]

Phacoemulsification with in-the-bag placement of a foldable IOL is a good option when combined with many vitreoretinal procedures. However, pars plana lens fragmentation with simultaneous or later sulcus placement of a posterior chamber IOL is still often used for more complex cases.[989] Secure wound closure is important to permit safe vitreoretinal maneuvers.[990-992] Surgeons should consider the nature of the posterior segment pathology and need for visualization when selecting the IOL style, biomaterial, and optic size.[549,550,993,994] Specifically, intraoperative visualization of the posterior segment may become impaired when a silicone optic comes into contact with silicone oil or a gas bubble.[549,550] 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.[995]

A mild myopic shift is recognized in some cases of combined surgery.[996,997]

Possible disadvantages of simultaneous cataract and vitreoretinal surgery include prolonged surgical time, cataract-wound dehiscence caused by globe manipulation during subsequent vitreoretinal 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.

A 2013 Cochrane study reviewed the effectiveness and safety of surgery for postvitrectomy cataract with respect to visual acuity, quality of life, and other outcomes.[998,999] The review was unable to identify any randomized or quasi-RCTs comparing cataract surgery with no cataract surgery for patients who developed cataracts following vitrectomy surgery and recommended a RCT to address this gap in evidence.

Cataract surgery following refractive surgery

Patients who have had prior corneal refractive surgery present a number of challenges for IOL-power calculation. In addition to an inability to measure 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. In addition, surgical strategies vary with the nature of the prior refractive surgery.

Following radial keratotomy, it is best to avoid having the new cataract-surgery incision cross or intersect pre-existing incisions, as this could lead to incision dehiscence, wound leak, delayed healing, and irregular astigmatism.[1000-1003] Microincision methods may be helpful in this situation, and when many incisions are present, a scleral incision may lessen the chance of involving the original incisions.

In the case of radial keratotomy, 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 will therefore fail to detect the full degree of central flattening.[1004,1005] The clinical history method (which requires knowledge of presurgical keratometry and refraction) is generally not helpful following radial keratotomy due to the common occurrence of progressive central corneal flattening (hyperopic drift) that may continue for years to decades. Certain specific forms of automated computerized videokeratography (topography or tomography) can help in determining true central corneal power.[1006,1007]

In general, prior laser refractive surgery does not cause anatomic challenges during cataract surgery. On the other hand, in cases with previously implanted phakic refractive IOLs, the refractive IOL must be removed prior to or concomitant with cataract surgery.

Each type of refractive surgery presents a unique problem for determining the correct IOL power. Following myopic laser vision correction, the cornea tends to have more positive spherical aberration than average and so would optically benefit from a more negative aspheric IOL. Conversely, after hyperopic laser correction, the cornea generally has a more negative asphericity and would benefit from a positively spherical IOL.[1008]

After excimer laser refractive surgery (by either surface or intrastromal photoablation), corneal-power readings with traditional keratometers, automated refractors, and topographers are often incorrect as result of the surgical alteration of the anterior corneal curvature and the changed relationship between anterior and posterior corneal powers. As a result, there is a tendency for hyperopic refractive errors after cataract surgery in eyes with prior myopic photoablation.[881,1009-1012] Similarly, eyes that have had prior hyperopic photoablation are prone to myopic optical errors after cataract surgery.[1013]

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.[1014-1024] 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. *(III, good quality, strong recommendation)*

For the most accurate IOL-power calculation methodologies for patients who have previously undergone radial keratotomy or myopic or hyperopic photoablation, the ASCRS has developed a regularly updated online IOL-power calculator available at http://iolcalc.ascrs.org/.[249,1025] Also, as mentioned in the Optical and Refractive Considerations section, intraoperative aberrometry may aid in IOL selection in postlaser vision-corrected eyes.[285]

Postoperative corneal hydration or edema and elevated IOP may amplify the effect of radial keratotomy incisions, causing transient hyperopia and changes in astigmatism. The timing of any further refractive surgical intervention can be delayed until the refraction is stable.[1000]

Cataract surgery and uveitis

There are special issues to consider when patients with uveitis undergo cataract surgery.[1026,1027] Patients with active inflammation, particularly those with anterior or intermediate uveitis, are at substantial risk for postoperative complications. A major potential problem, especially among patients with pre-existing iris damage or extensive posterior synechiae, is the development of postoperative 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 prior to cataract surgery will provide for appropriate prophylactic anti-inflammatory therapy and improve postsurgical outcomes.

There are many important factors to consider in the presence of uveitis. Ideally, inflammation should be inactive or controlled as much as possible prior to elective surgery.[858] Many uveitis specialists advocate 3 months or more of quiescence prior to surgery, as this reduces the risk of postoperative macular edema.[838,858,859] Even if the patient

is on chronic anti-inflammatory therapy, additional topical and/or oral corticosteroids are often recommended prior to surgery to pre-empt severe postoperative exacerbations.[839] In one study, preoperative treatment with oral corticosteroids seemed to decrease the risk of postoperative CME.[859] 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 previously controlled. *(III, good quality, strong recommendation)* Surgical planning should take into account the possible need for other procedures, which are often required because of associated uveitic complications, such as secondary glaucoma. *(III, good quality, strong recommendation)* Surgical procedures may need to be modified to manage pre-existing posterior synechiae, pupillary membranes, zonular compromise, and fibrotic scarring of the pupillary margin.

The safety of IOLs in most eyes with uveitis is now generally accepted. Intraocular lens material does not seem to be a major influence on the course of postoperative inflammation. However, a recent evidence-based review and meta-analysis indicates that some IOL materials may be associated with better outcomes than others.[838] In this study, eyes receiving acrylic IOLs or heparin-surface-modified (HSM) polymethylmethacrylate had better visual outcomes than those receiving non-HSM polymethylmethacrylate or silicone IOLs.[1028] 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. However, a 2014 Cochrane review found evidence of a superior effect of hydrophobic acrylic lenses over silicone lenses, specifically for posterior synechiae outcomes, but this effect was reported from a single study that suffered from potential performance and detection bias. The small sample sizes and heterogeneity in outcome reporting resulted in insufficient information to assess these and other types of IOL materials for cataract surgery for eyes with uveitis.[839] Lastly, a study of 171 eyes found a good long-term biocompatibility and safety profile in uveitic eyes receiving hydrophobic acrylic IOLs.[1029]

Intraocular lens-related complications may include inflammatory deposits, surface membrane formation, and inflammatory capsular complications capable of causing IOL subluxation. Leaving the 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, standard placement of the IOL haptics into the capsular bag is preferred; however, sulcus fixation of the haptics may allow the IOL 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.[835] 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 the angle anatomy is compromised.

Although the pupil may dilate poorly in eyes with uveitis, excessive iris manipulation should be minimized as much as possible to avoid worsening of the inflammation and posterior synechiae formation. 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 (intravenous, periocular, or intraocular) should be considered. *(III, good quality, strong recommendation)* Patients with uveitis are at risk of postoperative inflammatory exacerbation. Postoperatively, eyes with uveitis generally require 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.[1030] *(III, good quality, strong recommendation)*

Postoperative inflammation and CME generally respond to anti-inflammatory treatments. As with preoperative prophylactic treatment, postoperative coordination of management of uveitis patients along with the 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.[1031,1032] 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.[1033] When cataract surgery is contemplated in a functionally monocular patient, the ophthalmologist has an obligation to inform the patient that blindness is one of the risks of cataract surgery and that it can also result from worsening ocular comorbidity following surgery.[1034] *(III, good quality, strong recommendation)*

The ophthalmologist and patient should consider that delaying surgery until the cataract is very advanced may increase surgical risk and slow visual recovery. *(III, good quality, strong recommendation)*

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.[1035-1040] In addition, these studies demonstrate that binocular gain or summation is less likely when the visual acuities in the two eyes are dissimilar or when the individual is older. Patients with a cataract and dissimilar vision in the two eyes (or one eye with cataract extraction and the second eye with a cataract) demonstrate binocular inhibition.[1040] A large epidemiological study demonstrates that persons who exhibit binocular inhibition are more likely to have driving difficulties compared with those who do not have binocular inhibition.[1035] It is important to discuss this with patients who have potential anisometropia before proceeding with cataract surgery. These data taken together suggest an improvement in binocular visual function and quality of life if cataract surgery in the second eye provides similar visual acuities in the two eyes.

Studies comparing the outcomes of first- 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 only one eye.[117,1041-1046] Patients who had surgery in both eyes were significantly more satisfied with their visual function than patients who had surgery in only one eye.[1041,1047] Another 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.[1048] One study found that stereoacuity increased from 32% of patients after first-eye surgery to 90% after second-eye surgery. Also, binocular horizontal field of vision improved in 36% 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.[1049] Cataract surgery for both eyes is an appropriate treatment for patients with bilateral cataract-induced visual impairment.[1041,1043,1044,1050] *(I-, good quality, strong recommendation)*

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.[1051]

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. In patients whose anisometropia interferes with visual function, second-eye surgery may be appropriate at an earlier stage of cataract development.[1043,1052]

In some patients, a contact lens may resolve the anisometropia, and cataract surgery can then be deferred.

Determining the appropriate interval between the first-eye surgery and the second-eye surgery is influenced by several factors: the 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. Prior to performing second-eye surgery, the refractive error of the first eye should be determined in order to select the appropriate IOL power for the second eye.[1053,1054]

Immediate Sequential (Same Day) Bilateral Cataract Surgery

Most ophthalmologists do not perform immediate sequential bilateral cataract surgery. The rapid visual recovery and low complication rates associated with SICS under topical anesthesia have led to increased interest in this approach in some international centers,[1055-1068] particularly in health care delivery systems with long waiting times for cataract surgery in the second eye.[1055,1065-1067] Prospective comparative trials of immediate sequential (same day) versus delayed sequential (different day) cataract extraction document some cost reduction with same-day bilateral surgery and a short-term functional advantage.[1062-1067,1069,1070] Assuming the patient prefers cataract surgery in both eyes, immediate sequential bilateral surgery has advantages and disadvantages that must be carefully weighed and discussed.[1071] Foremost is the risk of potentially blinding complications in both eyes, such as endophthalmitis or TASS. For this reason, the second eye should be treated like the eye of a different patient using separate povidone iodine prepping, draping, instrumentation, and different supply lot numbers such as irrigating solutions, OVD, and medications. *(III, good quality, strong recommendation)* This may be especially true for compounding pharmacies. In published reviews, bilateral complications are rare and the procedure is safe,[1055-1061,1072,1073] but there have been case reports of bilateral endophthalmitis occurring with sequential surgery when these guidelines for strict separation of the two surgical setups were not followed.[1063,1064,1074,1075] If a complication should occur intraoperatively during the first eye surgery, then surgery on the second eye should be reconsidered and done at a later date. *(III, good quality, strong recommendation)*

Another potential disadvantage of immediate sequential bilateral surgery is the inability to adjust surgical plans for the second eye on the basis of results from the first-eye surgery.[1054] In addition to an unanticipated refractive outcome in the first eye, IOL selection for the second eye may also be altered because the patient decides on a different refractive target or type of IOL based on the first eye's outcome.[1054] One study did show that 5% of patients had a change of IOL power based on the results of the first eye and, with improving preoperative and intraoperative biometry, this number should improve over time.[1076]

Indications that have been reported for immediate sequential bilateral cataract surgery include the need for general anesthesia in the presence of bilateral visually significant cataracts, situations where travel for surgery and follow-up care is a significant hardship for the patient, and when the health of the patient may limit surgery to one surgical encounter.[1056,1059,1068]

Discharge from Surgical Facility

Typical criteria for discharge after ambulatory surgery are as follows:

◆ Vital signs are stable
◆ Preoperative mental state is restored
◆ Nausea and vomiting are controlled
◆ Pain is absent or minimal
◆ An escort is available if necessary
◆ Postsurgical care has been reviewed with the patient and/or escort and written postoperative instructions have been provided
◆ 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.[235] Ocular complications that may require hospitalization include hyphema, uncontrolled elevated IOP, threatened or actual expulsive suprachoroidal hemorrhage, retrobulbar hemorrhage, severe pain, 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, acute psychiatric disorientation, or other medical conditions requiring management in an acute-care setting with careful monitoring.

Situations under which extended observation might be warranted include the following:

◆ Medical conditions are present that require prolonged postoperative observation by nurses or other skilled personnel
◆ Patient is mentally debilitated or diagnosed as mentally ill
◆ Patient cannot exercise self-care (or responsible care is unavailable) during the immediate postoperative period
◆ Patient is functionally monocular and has had cataract surgery in the eye on which he or she is dependent

Postoperative Management

The operating ophthalmologist has the ultimate responsibility for the preoperative assessment and postoperative care of the patient, beginning with the determination of the need for surgery and ending with completion of the postoperative care contingent on medical stability of the patient.[1077] 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. *(III, good quality, strong recommendation)* 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.[232,1078] Comanagement is a relationship between an operating ophthalmologist and a nonoperating practitioner for shared responsibility in the postoperative care when the patient consents in writing to multiple providers, the services being performed are within the providers' respective scope of practice, and there is written agreement between the providers to share patient care. Transfer of care occurs when there is transfer of responsibility for a patient's care from one qualified health care provider operating within his or her scope of practice to another who also operates within his or her scope of practice.

The ophthalmologist who performs surgery has an obligation to inform patients about appropriate signs and symptoms of possible complications, eye protection, activities, medications, required visits, and details for access to emergency care. *(III, good quality, strong recommendation)* The ophthalmologist should also inform patients of their responsibility to follow advice and instructions provided during the postoperative phase and to notify the ophthalmologist promptly if problems occur. *(III, good quality, strong recommendation)* Patients should always have access to an ophthalmologist for appropriate care if serious problems arise. *(III, good quality, strong recommendation)*

Most ophthalmologists provide all postoperative care in their offices. Other members of a team of eye care professionals may also participate in the comanagement of postoperative care. The operating ophthalmologist is responsible to the patient for those aspects of postoperative care delegated to other eye care professionals.[232] Economic considerations should never influence the decision to comanage or the timing of a patient's transfer of care after surgery; such quid pro quo arrangements are unethical and often illegal.[1077] Any

delegation of a surgeon's postoperative responsibilities to another nonoperating practitioner and any payments to either party should be completely transparent to the patient and only done after obtaining the patient's informed consent in writing. Routine comanagement or transfer of care-referral arrangements are not appropriate. Instead, comanagement and transfer of care arrangements should be conducted pursuant to written patient-specific protocols. (See the Comprehensive Guidelines for the Co-Management of Ophthalmic Postoperative Care for detailed information.[1077])

Postoperative regimens of topically applied antibiotics, corticosteroids, NSAIDs, and oral analgesic agents vary among practitioners.[1079] There are no controlled investigations that establish optimal regimens for the use of topical agents. Therefore, it is the decision of the operating surgeon to use any or all of these products singly or in combination. 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, have rarely been reported for topical ocular NSAIDs.[1080-1082]

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 prompt and accurate diagnosis and treatment of complications of surgery, providing satisfactory optical correction, educating and supporting the patient, and reviewing postoperative instructions. Table 5 provides guidelines for follow-up based on consensus in the absence of evidence for optimal follow-up schedules. Prospective studies from the United Kingdom have reported that omitting an examination on the day after uncomplicated cataract surgery for the routine patient was associated with a low frequency of serious ocular complications.[1083-1086]

TABLE 5   POSTOPERATIVE FOLLOW-UP SCHEDULE

Patient Characteristics	First Visit	Subsequent Visits
Without high risks or signs or symptoms of possible complications following small-incision cataract surgery	Within 48 hours of surgery	Frequency and timing dependent on refraction, visual function, and medical condition of the eye
Functionally monocular; intraoperative complications; high risk of immediate postoperative complications, such as IOP spike	Within 24 hours of surgery	More frequent follow-up usually necessary

IOP = intraocular pressure

Patients should be instructed to contact the ophthalmologist promptly if they experience symptoms such as a significant reduction in vision, increasing pain, progressive redness, or periocular swelling, because these symptoms may indicate the onset of endophthalmitis. *(III, good quality, strong recommendation)*

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. 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. *(III, good quality, strong recommendation)*

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 patient's caretaker
◆ 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 retinal detachment. However, dilation is often critical in assessing anterior ocular concerns, such as capsular contracture or IOL malposition and other 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 refractive visit should be made to provide an accurate prescription for eyeglasses to allow for the patient's optimal visual function. *(III, good quality, strong recommendation)* The timing and frequency of refraction will depend on patient needs and the stability of the measurement. Sutures, if used, may be cut or removed by the ophthalmologist to reduce astigmatism. Optical correction can usually be prescribed between 1 and 4 weeks after small-incision cataract surgery[1087] 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. In a comparative study, the incidence of PCO was significantly higher at 1 year in the manual ECCE group than in the phacoemulsification group.[485,1088] The most common cause of PCO is proliferation and metaplasia of lens epithelial cells that remain in the capsular bag following cataract surgery.[1089,1090]

The onset of PCO from the time of surgery varies.[1091,1092] The frequency with which Nd:YAG laser posterior capsulotomy is performed also varies and has been reported in the range of 3% to 53% within 3 years.[1093] The Cataract PORT study reported a 19% incidence of PCO occurring within 4 months of cataract surgery.[106] More recently, well-designed clinical series with 3- to 5-year follow-up utilizing a sharp-edged optic design with either silicone or hydrophobic acrylic optics show posterior capsulotomy rates below 5%.[1094-1097]

Younger patients often have more significant rates of PCO following cataract surgery than older patients. A longitudinal study in Sweden found that at 10 years postoperatively 37% of patients under 65 at the time of surgery had been treated using Nd:YAG laser capsulotomy compared with 20% of the patients older than 65.[1098]

Results from a meta-analysis provide information on the efficacy of different IOL materials and optic edge designs in preventing PCO.[533] An analysis of 23 RCTs found that sharp-edged hydrophobic acrylic IOLs and silicone IOLs had less risk of PCO and Nd:YAG laser capsulotomy than PMMA IOLs and hydrophilic acrylic (hydrogel) IOLs. A 2010 Cochrane systematic review found no significant differences in PCO development among different IOL materials (PMMA, hydrogel, hydrophobic acrylic, and silicone).[1099] However, hydrogel IOLs tended to have higher PCO scores and the silicone IOLs had lower PCO scores than the other IOL materials. This analysis found a significantly lower PCO score and Nd:YAG laser capsulotomy rate with sharp-edged versus round-edged IOLs. A 2013 systematic analysis of nine randomized controlled trials demonstrated higher PCO scores and Nd:YAG laser capsulotomy rates at 1 and 2 years postoperatively for sharp-edged hydrophilic lenses than for sharp-edged hydrophobic acrylic lenses.[1100] However, one randomized trial indicated that the protective effect of the sharp-edged hydrophobic lens

may only delay the effect of PCO compared with round-edged silicone and round-edged PMMA after 12 years of follow-up.[1101]

Substantial evidence supports a lower PCO rate when the anterior capsulorrhexis completely overlaps the entire optic.[1102-1104] However, capsulorrhexis may be a less important factor with single-piece foldable acrylic IOLs.[1098]

Polishing of the anterior capsule has a variable effect on reducing PCO rates.[1105-1107] However, anterior capsule fibrosis and contracture is more frequent with silicone than with acrylic optic materials, and anterior capsule polishing may reduce this postoperative phenomenon.[1105,1106,1108] Anterior capsule contraction and anterior capsule opacification were found to be higher in an interrupted square-edge IOL versus a 360 continuous sharp-edge design.[1109] No difference in PCO rates has been found with more prolonged administration of topical corticosteroids or topical NSAIDs.[883-885]

Another condition treated by Nd:YAG laser capsulotomy is capsular distension syndrome characterized by a milky fluid behind the lens optic and anterior displacement of the lens, resulting in a myopic refractive shift.

Posterior Nd:YAG laser capsulotomy is an effective surgical procedure to clear the visual pathway and restore visual function, and to improve contrast sensitivity.[1110] The indication for performing Nd:YAG laser capsulotomy is PCO consistent with an impairment of vision to a level that does not meet the patient's functional needs or that critically interferes with visualization of the fundus. The decision to perform capsulotomy should take into account the benefits and risks of the laser surgery. *(III, good quality, strong recommendation)* 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. Multifocal IOLs and early PCO both reduce contrast sensitivity. Laser posterior capsulotomy should not be performed prophylactically (i.e., when the capsule remains clear). *(III, good quality, strong recommendation)* Same-day bilateral Nd:YAG laser capsulotomy may be appropriate when indicated. The eye should be inflammation free and the IOL stable prior to performing Nd:YAG laser capsulotomy.[1101] *(III, good quality, strong recommendation)*

Complications of Nd:YAG laser capsulotomy include increased IOP,[1111] retinal detachment, CME, corneal injury, iritis, vitritis, damage to the IOL, and dislocation of the IOL.[1112] There have been case reports of macular hole formation[1113,1114] and indolent endophthalmitis[1115] following Nd:YAG laser capsulotomy. A capsulotomy can complicate an IOL exchange. Axial myopia increases the risk of retinal detachment after Nd:YAG laser capsulotomy,[1116] as does pre-existing vitreoretinal disease, male gender, young age, vitreous prolapse into the anterior chamber, and spontaneous extension of the capsulotomy.[1117] Two case series reported a 0% to 0.4% incidence of retinal detachment 1 to 8 years following laser capsulotomies.[705,1118] In one of these series, there were no retinal detachments in eyes with an axial length less than 24.0 mm.[705] A case-control study found that, in the absence of a posterior capsule tear at the time of cataract surgery, subsequent Nd:YAG laser capsulotomy did not increase the risk of retinal detachment.[1119]

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.[1120,1121] 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.[1122-1127] Therefore, in high-risk patients, the surgeon should monitor the IOP in the early postoperative period. *(III, good quality, strong recommendation)* Treatment with topical corticosteroids, NSAIDs, or cycloplegic agents is dependent on the patient's risk factors and surgeon's preference.

Because retinal breaks or detachments are acute events that can occur weeks to 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.[1128]

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 formulate and carry out a treatment plan, including postoperative care.[231,232] 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. *(III, good quality, strong recommendation)* Cataract surgery, including use of the femtosecond laser, should be performed only by an appropriately trained ophthalmologist.[1129] *(III, good quality, strong recommendation)*

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. *(III, good quality, strong recommendation)*

Nearly all cataract surgery is performed in an outpatient setting, which may be in a hospital-based outpatient department (HOPD) or freestanding ambulatory surgery center (ASC). A Cochrane review has concluded there is no difference in outcome or increased risk of postoperative complications between outpatient and inpatient cataract surgery.[1130,1131]

The surgical facility should comply with local, state, and federal regulations and standards governing the particular setting of care. *(III, good quality, strong recommendation)* 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.[1132] *(III, good quality, strong recommendation)* 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 2010, a total of 1.82 million cataract procedures were performed on Medicare beneficiaries who were not enrolled in health maintenance organizations. Using projections of population growth and distribution and current age, approximately 3.3 million surgeries will be performed in 2020 and 4.4 million cataract surgeries will be performed in 2030 among individuals aged 65 and older in the United States.[1133] A longitudinal study of Americans 62 or older (n=8670 in 1998) estimated that the annual rate of cataract surgery was 5.3% for the period January 1, 1995 to December 31, 2002.[1134] The study also found that the prevalence of unilateral pseudophakia increased from 7.6% in 1998 (n=8670) to 9.8% in 2002 (n=6199) and that the prevalence of bilateral pseudophakia increased from 10.5% in 1998 to 22.3% in 2002. Additionally, a 2014 Beaver Dam Eye Study concluded that the incidence of lens extraction has increased over the past 20 years in persons older than 65, particularly in those participants without any clinically significant lens opacity and in persons with visual acuity better than 20/40 at an examination as measured 5 years before lens extraction took place.[1135]

When assessed across populations residing in different states or metropolitan areas, there is some variation in the rate of cataract surgery, but these differences are relatively low compared with geographic variations observed with other surgical procedures. 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.[1136] A higher concentration of ophthalmologists was not associated with a higher rate of cataract surgery. A decreased likelihood of undergoing cataract surgery was

reported among African American Medicare beneficiaries when compared with Caucasian Americans.[1136] The rate of cataract surgery in the Veterans Health Administration (VHA) ranged between 105 and 134 per 10,000 VHA beneficiaries in 2007. These figures include surgery performed in VHA hospitals and surgical centers and those performed outside the VHA system but paid for by the VHA.[1137]

The utilization of cataract surgery in the United States has been found to be appropriate for the majority of cases studied. A study at 10 academic medical centers found that 2% of cataract surgeries performed were classified as inappropriate based on available records.[1138] 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.[1138] Cataract surgery appropriateness 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).[1139,1140] 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 is 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.[1141] 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.[1142] More recent studies have added a self-reported visual function questionnaire.[1143] 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 of Cataract Surgery in the United States

Since the first freestanding ASCs were started in the early 1970s, there has been a significant movement of eye surgery from HOPDs to ASCs. According to the Medicare Payment Advisory Commission, ASCs may offer more convenient locations, shorter waiting times, and easier scheduling for patients compared with HOPDs.[1144] In 2009, 69% of cataract surgery with IOL insertion was performed in ASCs.[1144] Medicare payments to ASCs for all types of surgery totaled $3.2 billion or $102 per Medicare beneficiary in 2009.[1144] Cataract surgery with IOL implantation was the most frequently performed surgical service in ASCs in 2009, accounting for 18% of the volume.[1144] Eye procedures accounted for 46% of total Medicare ASC payments. In 2010, the Medicare facility payment to an ASC for cataract surgery was $961.34 and $1637.15 for an HOPD. Patients' coinsurance payments are lower in an ASC facility at $192 compared with $327 in HOPDs. Cataract surgery with IOL implantation accounted for 40% of Medicare eye-procedure payments.

The 2006 National Survey of Ambulatory Surgery by the Centers for Disease Control and Prevention's National Center for Health Statistics found that the total operating room times (including surgery and turnover) were over 50% longer in HOPDs.[1145]

In 2010, the national average surgeon reimbursement for cataract surgery/IOL implantation was $713.86. Since the institution of the Resource-Based Relative Value Scale in 1992, there has been a 40% decrease in this fee, not adjusted for inflation. The total cost for cataract surgery/IOL implantation for a Medicare beneficiary in the ASC setting is about $2335 for 2010. This includes the initial office evaluation as well as refraction, biometry, surgical facility fee, surgeon and anesthesia professional fees, and medications. The Medicare patient's copayment is approximately $450. Typically, the facility fee for cataract surgery/IOL implantation will be

approximately 50% higher in the HOPD setting. In the final 2016 Medicare Physician Fee Schedule calculations, the cataract code 66984 practice expense Relative Value Units was calculated at 8.98 and the total Relative Value Unit at 18.11, with a conversion factor of 35.8043. Overall, this represents a 1% reduction from 2015 of $650.40 to $642.39 with current consensus that CMS reimbursement for cataract surgery will continue to decline in the future.

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. In 2009 (latest year available), payment for cataract was $2.1 billion, which is 1.8% of total allowed charges.[1146]

Cost-Effectiveness of Cataract Surgery

Methods to evaluate whether the cost of a medical intervention is a good 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 hypothetical cost per QALY gained for cataract surgery in one eye was estimated at US$4500 in Sweden[1147] and US$2023 in the United States.[1148] In a U.S. study done in 2003, the estimated cost per QALY gained for cataract surgery in the second eye was US$2727.[1149] These calculations compare favorably with other medical treatments. Single-vessel coronary artery bypass surgery for disease of the left anterior descending artery costs $7000/QALY, treatment of arterial hypertension costs $58,000/QALY, and ambulatory peritoneal dialysis costs $90,000/QALY. A review assessed the 2012 cost utility of cataract surgery in the United States and compared 2012 cost-utility data with those from 2000. The authors measured patient value gain in QALYs and percent gain in quality of life as well as the cost-utility ratio using the dollars expended per QALY gained. Their results showed first-eye cataract surgery conferred 1.6212 QALYs over the 13-year model, a 20.8% quality-of-life gain. Bilateral cataract surgery conferred 2.8152 QALYs over 13 years, a 36.2% improvement in quality of life. The direct ophthalmic medical cost for unilateral cataract surgery in 2012 United States nominal dollars was $2653, an inflation-adjusted 34.2% less than in 2000 and 85% less than in 1985. Their conclusion was that cataract surgery in 2012 greatly improved quality of life and was highly cost-effective. Initial cataract surgery yielded an extraordinary 4567% financial return on investment to society over the 13-year model.[1150]

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.[1151] 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. One estimate of the present benefit value of cataract surgery is $95,000, which is far greater than the cost of treatment at $2300 to $3000. This value compares favorably with the estimated present values for treatments of other conditions: $20,000 for breast cancer, $6000 for depression, $240,000 for a low birthweight infant, and $70,000 for a heart attack. These various analyses suggest that on a relative basis, cataract surgery is very cost-effective and beneficial for the patient and society.[1152] The cost-effectiveness of new-technology IOLs, such as toric IOLs, was superior to the lifetime cost of eyeglasses.[1152]

Cost Considerations

Cataract surgery is the most cost-effective procedure performed in medicine today.[1150,1153,1154] Immediate sequential bilateral cataract surgery may be more cost-effective than delayed

sequential bilateral cataract surgery.[1069] With large projected increases in the elderly population worldwide, the significant cost burden of cataract surgery will continue to increase for every global medical system. Because of the societal imperative that cataract surgery be both safe and cost-effective, it is important to evaluate unproven and potentially unnecessary practices based on carefully monitored studies of surgical outcomes. For example, one paper evaluated a policy and procedural approach to a safe and effective use of multidose eye drops for cataract surgical patients and the cost benefit of multidose eye drops.[1155] In many countries, sterilization and aseptic protocols for ophthalmic surgery have been arbitrarily defined by national regulatory agencies. Many of these measures originated from studies in nonophthalmic specialties and may not be specifically validated for ophthalmic surgery, where the source of most infections is the patient's own eyelid and external ocular flora. For example, using infection-control protocols based on continuous monitoring of outcomes data, one eye hospital in India reported an endophthalmitis rate of only 0.09% (0.02% of phacoemulsification cases) in more than 42,000 consecutive cataract surgeries using short-cycle steam sterilization and continuous reuse of gowns, gloves, surgical tubing, and irrigating solutions.[349] Costlier new infection-control measures for ophthalmic surgery should not be arbitrarily imposed by regulatory agencies without evidence-based support. *(III, good quality, strong recommendation)*

New technology in cataract surgery, including advanced 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.[494]

Physician Quality Reporting System

The Physician Quality Reporting System program, initially launched by the Centers for Medicare and Medicaid Services in July 2007, encourages quality improvement through the use of clinical performance measures on a variety of clinical conditions.

The latest information on the Physician Quality Reporting System is available at www.aao.org/pqrs.

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.

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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; pseudoexfoliation 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[1156] or a reduced risk of cataract.[208-210,1157-1159]

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[1160]	1998	28,934 men	No effect of beta-carotene on risk for cataract surgery
Physicians' Health Study[1161]	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[1162]	2004	36,735 women	No effect of treatment on cataract development
Lutein/Zeaxanthin			
Age-Related Eye Disease Study 2 (AREDS2)[202]	2013	3159	No effect on rate of cataract surgery, development of posterior subcapsular or cortical cataracts, or vision loss
Multivitamin/Mineral			
Linxian Cataract[1163]	1993	2141	36% reduction in development of nuclear cataracts in a nutritionally deficient population
Nutritional Supplements and Age-Related Cataract[206]	2008	1020	34% reduction in nuclear cataract; twofold increased risk of posterior subcapsular cataract
Physicians' Health Study II[207]	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)[202,1164]	2013	3159	No effect on cataract progression
Riboflavin/Niacin			
Linxian Cataract[1163]	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[201]	2015	11,267 men	No effect of selenium on development of cataract
Vitamin C and E			
Physicians' Health Study II[1165]	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[1166]	2001	4629	No effect of treatment on the development or progression of cataracts
Antioxidants in Prevention of Cataracts Study[1167]	2006	798	No effect of treatment on progression of cataracts
Roche European American Cataract Trial[1168]	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[1160]	1998	28,934	No effect of vitamin E on risk for cataract surgery
SELECT Eye Endpoints Study[201]	2015	11,267 men	No effect of vitamin E on development of cataract
Vitamin E, Cataract and Age-Related Maculopathy Trial[1169]	2004	1193	No effect of treatment on the development or progression of cataracts
Women's Health Study[1170]	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[1171]	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[211]	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[210]	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)[210]	2011	Prospective cohort	27,670	Dietary intake	Vegetarians at lower risk of cataracts than meat eaters
Fat Intake					
Nurses' Health Study[209]	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[208]	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[1172]	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[1156]	1992	Prospective cohort	50,828 women	Supplement use	No association with multivitamin use and cataract extraction
Nurses' Health Study[1173]	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[1157]	1994	Prospective cohort	17,744 men	Supplement use	Reduced risk of cataracts
Cohort of Swedish men[199]	2013	Prospective cohort	31,120 men	Supplement use	Not associated with cataract risk
Riboflavin/Niacin					
Nurses' Health Study[1156]	1992	Prospective cohort	50,828 women	Total dietary intake	No association
Vitamin C					
Nurses' Health Study[1173]	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[1159]	2007	Prospective cohort	35,186	Total dietary intake	Reduced incidence of cataract diagnosis or extraction with higher vitamin C intake
Swedish Mammography Cohort[200]	2010	Prospective cohort	24,593 women	Supplement use	25% increased risk for cataract extraction for vitamin C supplement users
Cohort of Swedish men[199]	2013	Prospective cohort	31,120 men	Supplement use	21% increased risk of cataract
Twins U.K. Cohort[203]	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[1156]	1992	Prospective cohort	50,828 women	Total dietary intake and supplement	No association
Cohort of Swedish men[199]	2013	Prospective cohort	31,120 men	Supplement use	59% increased risk of cataract

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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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 2015; the search strategies were as follows. Specific limited update searches were conducted after July 2015.

PubMed Searches (limits: English, Publication date 1/10/11 – 7/13/2015)

Systematic Reviews: "cataract extraction"[MeSH]. 78 references

Clinical Study Category: "cataract extraction"[MeSH] diagnosis; narrow. 0 references

Clinical Study Category: "cataract extraction"[MeSH] therapy; narrow, specific search. 2 references

(endophthalmitis[MeSH]) AND ("cataract extraction"[MeSH]). 205 references

Corneal Transplantation/Penetrating Keratoplasty:
    ("cataract extraction"[MeSH]) AND (Keratoplasty, Penetrating [MeSH]). 33 references
    ("cataract extraction"[MeSH] AND ("corneal transplantation"[MeSH]). 98 references
    ("cataract extraction"[MeSH]) AND ("Endothelial Keratoplasty" OR DSAEK OR DSEK OR DMEK OR DLEK OR "posterior lamellar keratoplasty"). 71 references

Risk Factors:
    ("cataract/etiology"[MeSH]) AND ("risk factors"[MeSH]). 123 references
    ("cataract/epidemiology"[MeSH]) AND ("risk factors"[MeSH]). 117 references
    ("cataract/ethnology"[MeSH]) AND ("risk factors"[MeSH]). 5 references

"Cataract/prevention and control"[MAJR]. 113 references

("Cataract/epidemiology"[MeSH]) AND (Prevalence[MeSH]). 126 references

Rate – Appropriateness:
    (Cataract Extraction/statistics & numerical data[MeSH Subheading]) AND (appropriate*[Title/Abstract]). 10 references
    (Cataract Extraction[MeSH]) AND (appropriateness[Title/Abstract]). 2 references

Visual Function and Quality of Life (Note: This overlaps with the Outcomes search, which includes Visual Acuity [MeSH].):
    ("cataract extraction"[MeSH]) AND ("Quality of Life"[MeSH]). 73 references
    ("cataract extraction"[MeSH]) AND ("Activities of Daily Living"[MeSH]). 21 references
    ("cataract extraction"[MeSH]) AND ("Disability Evaluation"[MeSH]). 10 references
    ("cataract extraction"[MeSH]) AND ("Automobile Driving"[MeSH]). 5 references
    ("cataract extraction"[MeSH]) AND (depression[MeSH]). 6 references
    ("cataract extraction"[MeSH]) AND (anxiety[MeSH]). 5 references
    ("cataract extraction"[MeSH]) AND ("stress, Psychological"[MeSH]). 1 reference
    ("cataract extraction"[MeSH]) AND ("accidental falls"[MeSH]). 9 references

Evaluation of Visual Impairment:
    (cataract/diagnosis[MeSH]) AND ("visual acuity"[MeSH]). 125 references
    (cataract/diagnosis[MeSH]) AND ("contrast sensitivity"[MeSH]). 6 references
    (cataract/diagnosis[MeSH]) AND ("vision tests"[MeSH]). 134 references
    (cataract/diagnosis[MeSH]) AND (Questionnaires[MeSH]). 21 references
    (cataract[MeSH]) AND (Questionnaires[MeSH] AND ("sickness impact profile"[MeSH]). 27 references

Supplemental Ophthalmic Testing:
    (cataract/ultrasonography[MeSH]). 18 references
    ((cataract[MeSH]) OR ("cataract extraction"[MeSH])) AND ("potential vision"[tw]). 0 references
    ((cataract[MeSH]) OR ("cataract extraction"[MeSH])) AND ("ocular wavefront"[tw]). 4 references
    ((cataract[MeSH]) OR ("cataract extraction"[MeSH])) AND ("corneal topography"[tw]). 120 references
    ((cataract[MeSH]) OR ("cataract extraction"[MeSH])) AND ("potential acuity"[tw]). 0 references
    ((cataract[MeSH]) OR ("cataract extraction"[MeSH])) AND ("near card"[tw]). 1 reference
    ((cataract[MeSH]) OR ("cataract extraction"[MeSH])) AND ((glare disab*[tw]) OR (glare test*[tw])). 4 references
    ((cataract[MeSH]) OR ("cataract extraction"[MeSH])) AND ("scanning laser"[tw]). 0 references

((cataract[MeSH]) OR ("cataract extraction"[MeSH])) AND ("laser interferometer"[tw]). 0 references
((cataract[MeSH]) OR ("cataract extraction"[MeSH])) AND ("fluorescein angiography"[MeSH]). 42 references
((cataract[MeSH]) OR ("cataract extraction"[MeSH])) AND ("Tomography, Optical Coherence"[MAJR]). 94 references
((cataract[MeSH]) OR ("cataract extraction"[MeSH])) AND ("corneal pachymetry"[tw]). 38 references
((cataract[MeSH]) OR ("cataract extraction"[MeSH])) AND (specular microscop*[tw]). 29 references
((cataract[MeSH]) OR ("cataract extraction"[MeSH])) AND ("evoked potential"[tw]). 1 reference

Nonsurgical Management: Additional limit: Human
("cataract/chemically induced"[MeSH]) AND (corticosteroid*[Title/Abstract] OR steroid*[Title/Abstract] OR glucocorticoid*[Title/Abstract] OR glucosteroid*[Title/Abstract]). 29 references
(cataract[MeSH]) AND (smoking[MeSH]). 14 references
(cataract[MeSH]) AND ("dietary supplements"[MeSH]). 18 references
(cataract[MeSH]) AND (vitamins[MeSH]). 16 references
(cataract[MeSH]) AND (antioxidants[MeSH]). 65 references

Preoperative Medical Evaluation:
(("cataract extraction"[MeSH]) OR (cataract[MeSH])) AND ("Diagnostic Tests, Routine"[MeSH]). 3 references

Biometry and Intraocular Lens Power Calculation:
((cataract[MeSH]) OR ("cataract extraction"[MeSH])) AND (Biometry[MeSH]). 175 references
((cataract[MesH]) OR ("cataract extraction"[MeSH])) AND ("intraocular lens"[Title/Abstract] AND calculat*[Title/Abstract]). 164 references

Anesthesia:
(Anesthesia[MeSH]) AND ("cataract extraction"[MeSH]). 94 references

TASS (Toxic anterior segment syndrome):
"toxic anterior segment syndrome". 41 references

Surgical Techniques:
(incision[Title/Abstract] OR microincision[Title/Abstract]) AND ("cataract surgery"[Title/Abstract]). 293 references
("cataract extraction/methods"[MeSH]) AND ("Surgical Procedures, Minimally Invasive"[MeSH]). 0 references
("cataract surgery"[Title/Abstract]) AND (femtosecond[Title/Abstract]). 167 references

Optical & Refractive Considerations of Cataract Surgery (Note: There was a separate search for presbyopia-correcting IOLs, which were also discussed under the Second Eye Surgery section.):
("cataract extraction"[MeSH]) AND (Lenses, Intraocular[MeSH]) AND (("presbyopia-correcting"[Title/Abstract]) OR (aspheric[Title/Abstract]) OR (toric[Title/Abstract]) OR (accommodative[Title/Abstract]) OR (multifocal [Title/Abstract]) OR (dynamic[Title/Abstract])). 257 references

Outcomes:
("cataract extraction"[MAJR]) AND ("visual acuity"[MAJR]). 278 references
("cataract extraction"[MeSH]) AND ("Treatment Outcome"[MAJR]). 1 reference
("Outcome Assessment (Health Care)"[MAJR]) AND ("cataract extraction"[MeSH]). 19 references

Complications of Surgery & Complications of IOLs:
("cataract extraction"[MAJR]) AND ("Postoperative Complications"[MAJR]) AND ("Retrospective Studies"[MeSH]). 90 references
("cataract extraction"[MAJR]) AND ("Intraoperative Complications"[MAJR]) AND ("Retrospective Studies"[MeSH]). 26 references
("cataract extraction/adverse effects"[MAJR]) AND ("retrospective studies"[MeSH]). 69 references
("lenses, intraocular/adverse effects"[MeSH]) AND (cataract[tw] OR cataracts[tw]). 31 references
("lenses, intraocular"[MAJR]) AND ("Postoperative Complications"[MAJR]) AND (cataract[tw] OR cataracts[tw]). 60 references
("lenses, intraocular"[MAJR]) AND ("Intraoperative Complications"[MAJR]) AND (cataract[tw] OR cataracts[tw]). 4 references
((lens implantation, intraocular/adverse effects[MeSH]) OR (lens capsule, crystalline/injuries[MeSH])) AND (cataract[tw] OR cataracts[tw]). 83 references

Ocular Comorbidities:
("cataract extraction"[MeSH]) AND (comorbidity[MeSH]). 19 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND (Amblyopia[MeSH]). 2 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND (Uveitis[MeSH]). 10 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("Diabetic Retinopathy"[MeSH]). 18 references

("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("Macular Degeneration"[MeSH]). 26 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND (Glaucoma[MeSH]). 86 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("Exfoliation Syndrome"[MeSH]). 19 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("Retinopathy of Prematurity"[MeSH]). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND (Fuchs*[Title/Abstract]) AND (dystrophy[Title/Abstract]). 7 references

("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND (("cloudy cornea"[Title/Abstract]) OR ("cloudy corneas"[Title/Abstract])). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND (cloud*[Title/Abstract]) AND (cornea*[Title/Abstract]). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ((miotic[Title/Abstract] OR (miosis[Title/Abstract])) AND (pupil[Title/Abstract]). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND (deep*[Title/Abstract]) AND (set[Title/Abstract]). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND (brow[Title/Abstract]). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND (narrow[Title/Abstract]) AND ((lid[Title/Abstract]) OR (eyelid[Title/Abstract])). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ((high[Title/Abstract]) OR (highly[Title/Abstract])) AND (myop*[Title/Abstract]). 4 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ((high[Title/Abstract]) OR (highly[Title/Abstract])) AND (hyperopi*[Title/Abstract]). 3 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND (scleral[Title/Abstract]) AND (buckling[Title/Abstract]). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("posterior synechiae"[Title/Abstract]). 1 reference
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("posterior polar"[Title/Abstract]). 3 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND (brunescent[Title/Abstract]) AND (nuclear[Title/Abstract]). 0 reference
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("pars plana"[Title/Abstract]). 12 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("Filtering Surgery"[MeSH]) AND (glaucoma/surgery[MeSH]). 38 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("Filtering Surgery"[MeSH]) AND (glaucoma/surgery[MeSH]) AND (filt*[Title/Abstract]) AND (glaucoma[Title/Abstract]). 1 reference
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("Filtering Surgery"[MeSH]) AND (glaucoma/surgery[MeSH]) AND ("glaucoma filtration"[Title/Abstract]). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("Corneal Transplantation"[MeSH]) AND ("penetrating keratoplasty"[Title/Abstract]). 6 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("Refractive Surgical Procedures"[MeSH]) AND (keratorefractive[Title/Abstract]). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ((vitreoretinal[Title/Abstract]) OR (vitrectomy[tw])). 26 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("anterior microphthalmos"[Title/Abstract]). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("relative anterior"[Title/Abstract]). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("shallow anterior"[Title/Abstract]). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("prostatic hypertrophy"[Title/Abstract]). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND ("alpha-1a"[Title/Abstract]). 0 references
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND (("white cataract"[Title/Abstract]) OR ("mature cortical"[Title/Abstract])). 1 reference
("cataract extraction"[MeSH]) AND (cataract/complications[MeSH]) AND (zon*[Title/Abstract]) AND ((lax*[Title/Abstract]) OR (dehiscen*[Title/Abstract])). 4 references

Systemic Comorbidities:
("cataract extraction"[MeSH]) AND (Anticoagulants[MeSH]). 11 references
("cataract extraction"[MeSH]) AND ("Platelet Aggregation Inhibitors"[MeSH]). 5 references

Cataract Surgery & Vitreoretinal Surgery:
("cataract extraction"[MeSH]) AND (Vitrectomy[MeSH]) AND (combined[tw] OR combination[tw] OR simultaneous*[tw]). 88 references

("cataract extraction"[MeSH]) AND ("vitreoretinal surgery"[tw]) AND (combined[tw] OR combination[tw] OR simultaneous*[tw]). 8 references

Cataract Surgery Following Refractive Surgery:
("cataract surgery"[Title/Abstract]) AND ("refractive surgery"[Title/Abstract]). 43 references
(refractive[Title/Abstract]) AND (surgery[Title/Abstract]) AND ("intraocular lens"[Title/Abstract]) AND (calculat*[Title/Abstract]). 117 references

Cataract in the Functionally Monocular Patient:
("cataract extraction"[MeSH]) AND (Vision, Monocular[MeSH]). 7 references

Second Eye Surgery:
("cataract extraction"[MeSH]) AND "second eye". 42 references

Presbyopia-correcting intraocular lenses:
("presbyopia"[MeSH]) AND "lenses, intraocular"[MeSH]. 31 references

Simultaneous Bilateral Cataract Surgery:
("cataract extraction"[MeSH]) AND bilateral AND (same-day OR simultaneous OR sequential). 31 references

Postoperative Management, Postoperative Follow-up:
("cataract extraction"[MeSH]) AND ("Postoperative Care"[MeSH]) AND ("time factors" [MeSH]). 6 references
("cataract extraction"[MeSH]) AND (first AND review AND postoperative). 18 references

Posterior Capsular Opacification:
("cataract extraction"[MeSH]) AND ("posterior capsular opacification"[Title/Abstract]). 40 references

Cost of Cataract Surgery:
(("cost benefit analysis"[MeSH Terms] OR "cost control"[MeSH Terms] OR "cost savings"[MeSH Terms]) AND "cataract extraction"[MeSH Terms]). 33 references

Nutrition Studies:
(("cataract/epidemiology"[MeSH Terms]) OR ("cataract/prevention and control"[MeSH Terms])) AND (("nutrition assessment"[MeSH Terms]) OR ("food habits"[MeSH Terms]) OR ("diet"[MeSH Terms]) OR (diet surveys[MeSH Terms]) OR ("nutritional physiological phenomena"[MeSH Terms]) OR (fruit[MeSH Terms]) OR (vegetables[MeSH Terms]) OR ("vitamins"[MeSH Terms]) OR ("minerals"[MeSH Terms]) OR ("antioxidants"[MeSH Terms]) OR ("dietary supplements"[MeSH Terms]) OR ("beta carotene"[MeSH Terms]) OR ("riboflavin"[MeSH Terms]) OR ("niacin"[MeSH Terms]) OR ("ascorbic acid"[MeSH Terms]) OR ("vitamin e"[MeSH Terms])). 59 references

((cataract[MAJR]) AND (("nutrition assessment"[MeSH Terms]) OR ("food habits"[MeSH Terms]) OR ("diet"[MeSH Terms]) OR (diet surveys[MeSH Terms]) OR ("nutritional physiological phenomena"[MeSH Terms]) OR (fruit[MeSH Terms]) OR (vegetables[MeSH Terms]) OR ("vitamins"[MeSH Terms]) OR ("minerals"[MeSH Terms]) OR ("antioxidants"[MeSH Terms]) OR ("dietary supplements"[MeSH Terms]) OR ("beta carotene"[MeSH Terms]) OR ("riboflavin"[MeSH Terms]) OR ("niacin"[MeSH Terms]) OR ("ascorbic acid"[MeSH Terms]) OR ("vitamin e"[MeSH Terms]))). Additional limit: Humans. 65 references

Cataract Surgery & Uveitis:
("cataract extraction"[MeSH]) AND (Uveitis[MeSH]) AND (combined[tw] OR combination[tw] OR simultaneous*[tw]). 14 references

Cataract Surgery & Immunosuppression: Additional limit: Humans
("Cataract Extraction"[Mesh]) AND "Immunosuppression"[Mesh]. 1 reference

Lens Implantation: Additional limit: Humans, All Adult: 19+ years, Clinical Trial, Meta-Analysis.
"lens implantation, intraocular"[MeSH Terms]. 284 references

Cochrane Searches (Publication date 1/10/11 – 7/13/2015)

MeSH descriptor Cataract Extraction explode all trees in Cochrane Database of Systematic Reviews. 13 references

MeSH descriptor Cataract Extraction explode all trees in Other Reviews. 26 references

MeSH descriptor Cataract Extraction explode all trees in Technology Assessments. 12 references

MeSH descriptor Cataract Extraction explode all trees in Economic Evaluations. 18 references

LIST OF ABBREVIATIONS

ADVS: Activities of Daily Vision Scale

AMD: age-related macular degeneration

ARC: age-related cataract

AREDS: Age-Related Eye Disease Study

ASC: ambulatory surgery center

ASCRS: American Society of Cataract and Refractive Surgery

BCVA: best-corrected visual acuity

CCC: continuous curvilinear capsulorrhexis

CME: cystoid macular edema

D: diopter

DME: diabetic macular edema

DSEK: Descemet stripping endothelial keratoplasty

DMEK: Descemet membrane endothelial keratoplasty

ECCE: extracapsular cataract extraction

ESCRS: European Society of Cataract and Refractive Surgeons

EVS: Endophthalmitis Vitrectomy Study

FLACS: femtosecond laser-assisted cataract surgery

HEMA: hydroxy ethyl methacrylate

HOPD: hospital-based outpatient department

HORV: hemorrhagic occlusive retinal vasculitis

HSM: heparin-surface-modified

ICCE: intracapsular cataract extraction

IFIS: intraoperative floppy iris syndrome

IOL: intraocular lens

IOP: intraocular pressure

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

PMMA: polymethyl methacrylate

PORT: Patient Outcomes Research Team

PPP: Preferred Practice Pattern

PSC: posterior subcapsular cataract

QALY: quality-adjusted life year

RCT: randomized controlled trial

SICS: small-incision cataract surgery

TASS: toxic anterior segment syndrome

VEGF: vascular endothelial growth factor

VF-14: visual function index

VHA: Veterans Health Administration

RELATED ACADEMY MATERIALS

Basic and Clinical Science Course
    Lens and Cataract (Section 11, 2016–2017)

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 (2014)
    Enhanced Lens Options for Cataract Surgery (2014)

Patient Education Brochures
    Cataract (2016)
    Cataract (Spanish: Catarata) (2016)
    Cataract Surgery (2016)
    Eye Myths & Facts (2014)
    Seeing Well as You Grow Older (2016)

Patient Education Downloadable Videos
    Cataract and Refractive Surgery Patient Education Video Collection (2015)
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Patient Safety Statement – Free downloads available at www.aao.org/guidelines-browse?filter=patientsafetyguideline.
    Recommendations of American Academy of Ophthalmology Wrong-Site Task Force (2014)

Performance Improvement CME
    Wrong Site/Wrong IOL Surgery Performance Improvement CME – Available at: www.aao.org/pi-cme/wrong-site-wrong-iol (login required)

Preferred Practice Pattern® Guidelines – Free downloads available at www.aao.org/ppp.
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To order any of these materials, except for the free materials, please contact the Academy's Customer Service at 866.561.8558 (U.S. only) or 415.561.8540 or www.aao.org/store.

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