

PREFERRED PRACTICE PATTERN®



Cataract in the Adult Eye

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CATARACT AND ANTERIOR SEGMENT PREFERRED PRACTICE PATTERN DEVELOPMENT PROCESS AND PARTICIPANTS

The **Cataract and Anterior Segment Preferred Practice Pattern® (PPP) Panel** members wrote the Cataract in the Adult Eye Preferred Practice Pattern. The **Cataract and Anterior Segment Preferred Practice Pattern® Consulting Work Group** members drafted certain sections of the document, which the Panel members reviewed and approved. Over the course of two years, the PPP Panel members discussed and reviewed successive drafts of the document, meeting in person three times in that period and conducting other review by e-mail discussion, to develop a consensus over the final version of the document.

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The **Cataract and Anterior Segment Preferred Practice Pattern® Review Panel** members were responsible for reviewing the document specifically for any evidence of bias from relationships with companies of the Writing Panel or Work Group members. These panel members were selected for their expertise, objectivity, and lack of relationships with companies related to the subject of the document. This procedure was undertaken to comply with the Council of Medical Specialty Societies' Code for Interactions with Companies because work on the PPP started in October 2009, before the Academy adopted the Code. Overall, the guideline development process for this Preferred Practice Pattern is in compliance with the Council of Medical Specialty Societies' Code.

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The **Preferred Practice Patterns Committee** members reviewed and discussed the document during a meeting in May 2011. 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 July 2011. All those returning comments were required to provide disclosure of relevant relationships with industry to have their comments considered. Members of the Cataract and Anterior Segment Preferred Practice Pattern Panel reviewed and discussed these comments and determined revisions to the document. The following organizations and individuals returned comments.

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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 guidelines called Preferred Practice Patterns that **identify characteristics and components of quality eye care**. Appendix 1 describes the core criteria of quality eye care.

The Preferred Practice Pattern® (PPP) 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.

Preferred Practice Patterns 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 Patterns 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 PPPs 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 <http://one.aao.org/CE/PracticeGuidelines/PPP.aspx>) to comply with the Code.

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 Network¹ (SIGN) and the Grading of Recommendations Assessment, Development and Evaluation² (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 SIGN¹ 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 GRADE² 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 GRADE² 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

- ◆ Key recommendations for care ratings are listed in the Highlighted Findings and Recommendations for Care section. A key recommendation may address an area of controversy for which there is insufficient evidence to make a recommendation.
- ◆ Literature searches to update the PPP were undertaken in February 2010 in PubMed and the Cochrane Library. Additional searches were undertaken in March 2010; searches were last updated in January 2011. Complete details of the literature search are available at www.aao.org/ppp.



HIGHLIGHTED FINDINGS AND RECOMMENDATIONS FOR CARE

Cataract is a progressive, chronic, age-related disease affecting a large number of people over the age of 50. Cataract surgery is one of the most highly successful treatments in the history of medicine. Without surgery, patients would experience steady decline in visual and physical function. With surgery, patients rapidly recover with excellent vision and the ability to resume regular activities of daily living. The planning and decision-making process for cataract surgery is complex and intricate, involving not only judgment about appropriate treatment and surgical techniques but also about antibiotic prophylaxis, device selection (intraocular lenses [IOLs], ophthalmic viscosurgical devices [OVDs]), and prevention of complications. Continued innovation in surgical technique, IOLs, and antibiotic prophylaxis has improved safety and efficacy. The following list highlights important findings and recommendations for care from this comprehensive revision of the PPP.

1. *Cataract surgery should be recommended when indicated because of proven effectiveness in enhancing quality of life. (strong recommendation, moderate evidence)*

Numerous studies have documented that cataract extraction can markedly improve a patient's activities of daily living.⁴⁻⁷ These activities may include basic functions such as walking, driving, maintaining an occupation, and caring for personal needs; they may also extend to hobbies, enabling participation in social and community activities, and the reduction of ocular imbalance and troublesome refractive states.^{5,8-13} Scientific literature further provides support for a decreased risk of injury from falls and automobile accidents, improved mental health, and a general sense of well-being following cataract surgery.¹⁴⁻²⁰ Such improvements in overall quality of life cannot be predicted or judged solely by single measures of visual function such as Snellen acuity, because problems with glare, contrast sensitivity, color perception, aberration, and binocularity directly impact a patient's level of visual impairment.^{8,9,21-26}

2. *Cataract surgery should be recommended when indicated because of its cost-effectiveness in relation to other accepted treatments. (strong recommendation, moderate evidence)*

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 \$95,000,²⁷ which is far greater than the cost of treatment at \$2300 to \$3000. This value compares favorably with the estimated present values for other treatments: \$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 demonstrate that on a relative basis, cataract surgery is very cost-effective and beneficial for the patient and society.

3. *The decision to recommend cataract surgery should be based on consideration of the following factors: visual acuity, visual impairment, and potential for functional benefits. (strong recommendation, good evidence)*

There is no single test or measure that adequately describes the effect of a cataract on a patient's visual status or functional ability.²⁸ Therefore, no single test can properly define the threshold for performing cataract surgery. Though various methods of acuity measurement have long been considered the primary determinant for surgical appropriateness, the decision to recommend cataract surgery should not be made solely on this basis.^{4,23} For example, surgery for nonadvanced cataract in symptomatic patients with relatively good Snellen visual acuity often provides significant functional benefits.²⁹ Standardized evaluation of impairment of visual function and activities of daily living has been shown to correlate with expected improvement and satisfaction after cataract surgery. Several of these validated testing instruments and recent modifications are available for clinical use.^{4,23,24,30-33}

4. *Cataract surgery is a procedure appropriately utilized in the United States.*

(strong recommendation, moderate evidence)

Cataract extraction ranks among the most commonly performed surgical interventions in the United States. Assessment of appropriateness is therefore of particular interest and importance. Several studies of cataract surgery in the United States have shown utilization to be appropriate in the majority of cases evaluated.³⁴ 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. Preoperative evaluation to identify appropriate candidates should include thorough ophthalmic examination, patient-centered visual function evaluation, and patient education about treatment options prior to consent for surgery.

5. *Ophthalmologists and other physicians managing patients taking alpha-antagonists should be aware of the risks of intraoperative floppy iris syndrome (IFIS).*

(strong recommendation, good evidence)

Intraoperative floppy iris syndrome is associated with a higher rate of surgical complications, particularly when it is not recognized or anticipated.³⁵⁻³⁹ Pupil stretching and sphincterotomies are ineffective in these eyes, and pharmacologic approaches, such as intracameral epinephrine, viscomydriasis, and pupil expansion devices, either alone or in combination, should be used to manage IFIS.³⁵⁻³⁷ Patients should be questioned about current or prior use of alpha-antagonists in general and tamsulosin in particular. The risk of IFIS is greater with tamsulosin than with nonselective alpha-antagonists.⁴⁰

6. *The intraocular pressure (IOP) lowering effect of cataract surgery should be considered in the overall management of the patient.*

(strong recommendation, moderate evidence)

Phacoemulsification cataract surgery alone has been shown to reduce IOP in patients without glaucoma.⁴¹⁻⁴⁴ It also has been shown to be of benefit in lowering IOP in patients with angle-closure glaucoma.⁴⁵⁻⁴⁷ In patients with open-angle glaucoma, the IOP lowering associated with phacoemulsification cataract surgery alone may be of limited benefit.^{45,48}

7. *Ophthalmologists should be aware of increased antibiotic resistance in the general population.*

(strong recommendation, moderate evidence)

While staphylococcal species have been shown to be the most common organism cultured from cases of postoperative infectious endophthalmitis,⁴⁹⁻⁵¹ increasing resistance of these organisms to commonly used antibiotics is a major concern today.⁵²⁻⁵⁵ What started as penicillin resistance has progressed over time to common resistance for many antibiotics, including all of the presently used fluoroquinolones.⁵²⁻⁵⁵ These multidrug resistant bacteria have become so common that they are now present in the majority of patients who come for routine cataract surgery in many regions of the United States today.⁵⁶

8. *The optimum dosing and route of administration of antibiotics should be considered in order to achieve a high intraocular concentration immediately following surgery.*

(strong recommendation, moderate evidence)

With bacterial resistance an ever growing problem, it is becoming increasingly important to ensure that high concentrations of currently available antibiotics are present inside the eye, where a bacterial inoculum might reside. Although topical antibiotics may reach intraocular therapeutic levels for many bacteria, only intracameral antibiotics at the end of the case guarantees suprathreshold antibiotic levels for an extended period of time.⁵⁷ Evidence that this approach is efficacious is growing.⁵⁸⁻⁶⁰ Topical antibiotic eyedrops can be additive to intracameral antibiotics; however, if used alone they should be given frequently the day of surgery and not held until the next day.⁶¹⁻⁶⁵ There is less evidence that subconjunctival antibiotics are equally efficacious when compared with topical and intracameral antibiotics.⁶⁶

9. ***Although the incidence is rare, ophthalmologists should be aware of the potential risk of toxic anterior segment syndrome (TASS). (strong recommendation, moderate evidence)***

In one large series of 26,408 consecutive cataract surgeries, the incidence of TASS was 0.22%.⁶⁷ An evaluation of common risk factors associated with TASS looked at submitted TASS questionnaires and results from site visits from 2006 through 2009. The most common factors associated with TASS were related to inadequate cleaning and sterilization of ophthalmic instruments, such as insufficient flushing of phacoemulsification and irrigation/aspiration handpieces, as well as the use of enzymatic cleaners, detergents, and ultrasound baths.⁶⁸

10. ***Absent a normal capsular bag, ophthalmologists should determine whether the power and design of an IOL intended for capsular bag fixation is or is not appropriate for ciliary sulcus placement. (strong recommendation, moderate evidence)***

Optimal characteristics of a sulcus-fixated posterior chamber intraocular lens include sufficient overall length, posterior haptic angulation, and the absence of sharp anterior optic edges.⁶⁹ Intraocular lenses, such as single-piece acrylic designs that are intended solely for the capsular bag, should not be placed in the ciliary sulcus because they have been associated with pigment dispersion, elevated IOP, intraocular hemorrhage, and cystoid macular edema. Backup IOLs in appropriate powers, sizes, and designs should be available for every cataract procedure.⁶⁹⁻⁷¹ Anticipating a more anterior location of the optic, the power of an IOL placed in the ciliary sulcus should be reduced relative to that calculated for the same IOL when placed in the capsular bag (but less so when capture of the optic posterior to the capsulorrhexis can be achieved).^{72,73} Optic capture also reduces reliance on adequate haptic length to provide optic centration and stability.⁷⁴ Because noncapsular bag fixation may increase the potential for optic tilt and decentration, the surgeon should reconsider whether multifocal IOLs or those with higher degrees of negative spherical aberration should be implanted.^{75,76}

11. ***Safety protocols should be in place to prevent the occurrence of wrong-site surgery. (strong recommendation, moderate evidence)***

Steps taken before the surgery day, on the day of surgery, and when procedures dependent on preoperative calculation are undertaken can minimize the incidence of preventable surgical errors such as surgical site (e.g., wrong eye) and surgical procedure (e.g., wrong IOL implant).⁷⁷⁻⁸² The Wrong-Site Wrong-IOL Checklist (see Appendix 3) is an example of how to document in the surgery chart that all the appropriate steps have been taken in preventing wrong-site and wrong-surgery events.



INTRODUCTION

DISEASE DEFINITION

A cataract is a degradation of the optical quality of the crystalline lens (ICD-9 #366.1x).

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 the patient's visual and functional status and on quality of life
- ◆ Educate the patient about the impact of a cataract on vision, functional activity, and natural history as well as the benefits and risks of surgical and other alternatives so that the patient can make an informed decision about treatment options
- ◆ Establish criteria for a successful treatment outcome with the patient
- ◆ Perform cataract surgery when there is the expectation that it will benefit the patient's function and when the patient elects this option
- ◆ Perform surgery when indicated for management of coexistent ocular disease
- ◆ Provide necessary postoperative care, rehabilitation, and treatment of any complications



BACKGROUND

PREVALENCE

Cataracts are the leading cause of blindness worldwide and remain an important cause of blindness and visual impairment in the United States, accounting for approximately 50% of visual impairment in adults over the age of 40.⁸³ Cataracts are the leading cause of treatable blindness among Americans of African descent age 40 and older and are the leading cause of visual impairment among Americans of African, Hispanic/Latino, and European descent.^{83,84}

There are several different types of cataracts: nuclear, cortical (spokelike), 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.⁸⁵⁻⁸⁹ Nuclear cataracts consist of a central opacification or coloration that interferes with visual function. There are different types of nuclear cataracts, accompanied by either brunescence, opalescence, or both.⁹⁰ Nuclear cataracts tend to progress slowly and affect distance vision more than near vision. 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. 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 (PSC) cataracts can cause substantial visual impairment if they affect the axial region of the lens. Posterior subcapsular cataracts are found more often in younger patients than are nuclear or cortical cataracts. Patients often have glare and poor vision with bright lighting, and their near vision is typically more affected than distance vision. Two population-based studies found that of the three types, PSC cataracts are associated with the greatest rate of cataract surgery.^{91,92} In an older population (mean age 79 years) undergoing cataract surgery, however, nuclear cataracts were most frequently encountered.⁹³

Cataract affects over 22 million Americans age 40 and older, or about 1 in every 6 people in this age range. By age 80, more than half of all Americans have cataracts.⁹⁴ The Eye Diseases Prevalence

Research Group estimated that the number of individuals with cataracts will increase by 50% by 2020, based on U.S. Census population estimates.⁸³

Studies have found racial differences in the prevalence of different cataract types. In the Salisbury Eye Evaluation Study, Americans of African descent had a four times greater chance of having cortical opacities than Americans of European descent, and Americans of European descent were more likely to have nuclear and PSC opacities.⁹⁵ The Los Angeles Latino Eye Study of individuals 40 years old or older found that cortical opacities were the most frequent type of lens opacity.⁹⁶

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 topical, systemic, or inhaled oral corticosteroids; and prior intraocular surgery.⁹⁷⁻¹⁰⁹

Most studies are observational and can strongly suggest an association, but they cannot prove a causative effect because they did not measure cataract development or exposure to the risk factor in a standardized fashion.^{97,110}

NATURAL HISTORY

The natural history of all types of cataracts is variable, unpredictable, and related in some ways to type. 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 take on a yellow-to-brown coloration, changing the transparency and refractive index of the lens. Nuclear sclerosis and yellowing are considered a normal part of the aging process.

Cataract is a progressive disease. Once visual acuity and function start declining, the natural history is a steady decline without any chance of recovery. In three studies, which used different scales for progression of cataracts, there is evidence that cataracts progress over time. In the Barbados Eye Studies, individuals with pre-existing lens opacities had cumulative 9-year progression rates of 22.0% for cortical, 17.8% for nuclear, and 25.8% for PSC opacities.¹¹¹ The Melbourne Visual Impairment Project reported cumulative 5-year progression rates of 14.3% for cortical, 19.3% for nuclear, and 20.0% for PSC opacities.¹¹² In the Longitudinal Study of Cataract, individuals with pre-existing lens opacities had cumulative 5-year progression rates of 16.2% for cortical, 45.8% for nuclear, and 55.1% for PSC opacities.^{113,114}

PREVENTION

Several studies show a linkage of smoking with nuclear sclerosis and demonstrated a dose-response effect.¹¹⁵⁻¹²⁴ Findings from studies indicate a reduced risk of cataracts in past smokers compared with current smokers, demonstrating a benefit from smoking cessation.^{115,118,124,125} Thus, smoking cessation is a reasonable precaution to recommend to patients.

Cumulative lifetime exposure to ultraviolet-B radiation has been associated with lens opacities¹²⁶⁻¹³¹; therefore, brimmed hats and ultraviolet-B blocking sunglasses are reasonable precautions to recommend to patients.¹³²

A systematic review and eight randomized controlled trials of nutritional or vitamin supplementation published after the systematic review showed no significant effect in delaying the onset or progression of cataracts.¹³³⁻¹⁴¹ Another trial had inconclusive results because a statistically significant protective effect of supplementation with vitamins C and E and beta-carotene was found in the study arm with U.S. participants, but no effect was noted in the study arm with United Kingdom participants.¹⁴² After 9 years of follow-up, a randomized trial of multivitamin/mineral supplementation found fewer nuclear cataracts but more PSC cataracts in the group taking supplements compared with the placebo group.¹⁴³ A trial conducted in a nutritionally deficient population in rural China did show a beneficial effect of supplementation.¹⁴⁴ This trial was designed as a cancer intervention study, and participants had eye examinations only at the end of the study. Because this population had chronic deficiencies of multiple nutrients, the results may not be generalizable to better-nourished populations. Appendix 2 summarizes studies of nutrition and cataracts. 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.¹⁴¹ In those patients taking vitamin/mineral supplements of the

TABLE 1 RISK FACTORS ASSOCIATED WITH INCREASED RISK OF CATARACTS

Cataract Type	Associated Risk Factor	Type of Study	Risk
Subtypes not identified in study	Aspirin use	Randomized trials ¹⁴⁵⁻¹⁴⁸	No evidence of benefit
		Observational ¹⁴⁹	Increased risk
	Diabetes	Observational ^{104,105}	Increased risk
	Inhaled corticosteroid use	Case-control ^{99,101}	Increased risk in patients age 40 and older
		Case control ¹⁵⁰	Increased risk in patients age 65 and older
		Case-control ¹⁵¹	Increased risk in patients age 70 and older
	Nasal corticosteroid use	Case control ¹⁵⁰	No increased risk
	Ionizing radiation (low and high dose)	Observational ¹⁰⁶	Increased risk
Cortical	Smoking	Observational ¹²⁴	Increased risk
	Diabetes	Observational ¹⁰³⁻¹⁰⁵	Increased risk
	Family history	Observational ^{127,152-155}	Increased risk
	Hypertension	Observational ¹⁰⁵	Increased risk
	Ionizing radiation (low and high dose)	Observational ¹⁰⁷	Increased risk
	Myopia (>1 D)	Observational ¹²⁰	Increased risk
	Obesity	Observational ^{105,156}	Increased risk
	Systemic corticosteroid use	Observational ¹⁰⁰	Increased risk
Nuclear	Ultraviolet B light exposure	Observational ^{126,127,131}	Increased risk
	Diabetes	Observational ¹⁰⁵	Increased risk
	Family history	Observational ^{127,154,157,158}	Increased risk
	Hypertension	Observational ¹⁵⁹	Increased risk if taking topical or systemic beta blockers
	Prior PPV	Observational ¹⁰⁹	Increased risk
	Smoking	Observational ^{115-120,160,161}	Increased risk
Posterior subcapsular	Ultraviolet B light exposure	Case-control ¹³⁰	Increased risk
	Inhaled corticosteroid use	Population-based cross-sectional ⁹⁸	Increased risk in patients aged 49 and older
	Ionizing radiation (low and high dose)	Observational ¹⁰⁷	Increased risk
	Obesity	Observational ¹⁵⁶	Increased risk
	Ocular trauma	Cross-sectional ¹⁶²	Increased risk
	Prior PPV	Observational ¹⁰⁹	Increased risk
	Retinitis pigmentosa	Case series ¹⁶³⁻¹⁶⁵	Increased risk
	Topical corticosteroid use	Case series ¹⁶⁶	Increased risk
Mixed	Systemic corticosteroid use	Observational ¹⁰²	Increased risk
	Prior PPV	Observational ¹⁰⁹	Increased risk
	Tobacco use (smoking and smokeless)	Observational ¹⁶⁷	Increased risk
	Ultraviolet B light exposure	Observational ¹²⁶	Increased risk

D = diopters; PPV = pars plana vitrectomy

formulation used in the Age Related Eye Disease Study, none of the vitamin/mineral supplements appear to demonstrate a beneficial effect on cataractogenesis to date.^{133-138,168} Therefore, no recommendations for the use of nutritional supplements to prevent cataracts or delay progression can be made at this time. If asked, ophthalmologists should counsel patients that there are no preventive nutritional supplements for cataract.

Three recent studies evaluated the use of statins to reduce incidence of cataract. One study, a prospective cohort study, concluded there was an increased incidence of cataract in patients taking any of the statin formulations.¹⁶⁹ The Beaver Dam Study and another prospective cohort study reached the opposite conclusion, that statin use appears to decrease cataract risk.^{170,171}

Long-term users of inhaled or oral corticosteroids are at higher risk for cataract formation.⁹⁸⁻¹⁰²

Patients with diabetes mellitus are at higher risk for cataract formation,¹⁰³⁻¹⁰⁵ and so prevention and proper treatment of type 2 diabetes may have the additional benefit of reducing the risk of cataract.

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; perception of color; adaptation; and visual processing speed.^{8,21,22} Visual function also can be measured in terms of functional disability caused by visual impairment.^{9,23-26} Many activities of daily living require function of more than one of these visual components.

Improved function and quality of life are the treatment outcomes that are most critical and applicable to the patient. In well-designed observational studies, cataract surgery consistently has been shown to have a significant impact on vision-dependent function; up to 90% of patients undergoing first-eye cataract surgery note improvement in functional status and satisfaction with vision.⁴⁻⁷ Several studies have reported an association between improved visual function after cataract surgery and an improved health-related quality of life.^{5,8-13} Visual function plays an important role in physical function and well-being,¹⁴⁻¹⁷ particularly in terms of mobility.^{12,172,173} The loss of visual function in the elderly is associated with a decline in physical and mental functioning as well as in independence in activities of daily living,^{174,175} including night-time driving, daytime driving, community activities, and home activities. A long-term (10-year) evaluation of patients in the Blue Mountain Study found that cataract surgery patients had a significant improvement in the mental health domain scores from the SF-36 questionnaire.¹⁷⁶ Cataract surgery may also improve insomnia.^{177,178}

Visual impairment is an important risk factor for falls^{18,19} and for hip fracture²⁰; poor depth perception and decreased contrast sensitivity have been found to independently increase the risk of hip fracture.¹⁷⁹ In a randomized controlled trial, first-eye cataract surgery was found to reduce the rate of falling and fracture by 34% over a 12-month period.¹² Similar improvement following second-eye surgery has also been confirmed.¹⁷³ Visual loss from cataracts and the increased risk of falls may be a contributing factor for nursing home placement.¹⁸⁰ Visual impairment, in particular a decrease of visual acuity and contrast sensitivity, has been shown to be associated with difficulties in driving.^{22,181-184} Drivers with visually significant cataracts were 2.5 times more likely to have had an at-fault involvement in a motor vehicle crash over a 5-year period compared with drivers without cataracts.¹⁸⁵ When older adults with cataracts who have undergone surgery are compared with those who did not undergo surgery, motor vehicle crash rates in the 4 to 6 years of follow-up were halved in the surgery group.¹⁸⁶ One large study found that in an assessment of patients' visual function pre- and postoperatively, the largest improvements were noted for "driving during the day," "self-care activities," and "driving during the night."¹⁸⁷

In summary, there are numerous studies showing 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.

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
- ◆ 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 **physical function** as a critical 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 a second critical outcome of cataract surgery includes the following benefits:
- ◆ Improved self-esteem and independence
 - ◆ Increased ability to avoid injury
 - ◆ Increased social contact and ability to participate in social activities
 - ◆ Relief from fear of blindness



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 or affect the cataract surgical plan or ultimate outcome.

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. The latter may be measured by tests of contrast sensitivity, glare disability, or visual acuity. With newer technology, it is also possible to objectively measure higher-order aberrations from cataracts that compromise visual acuity and quality.^{188,189} Over time, patients adapt to their visual impairment and may fail to notice functional decline that accompanies the insidious progression of a typical cataract.

There is no single test or measure that adequately describes the effect of a cataract on a patient's visual status or functional ability.²⁸ Similarly, no single test can properly define the threshold for performing cataract surgery. The Snellen visual acuity chart is an excellent method for testing distance refractive error (e.g., myopia, hyperopia, astigmatism) in healthy eyes, and it is in wide clinical use. Although poor preoperative visual acuity does correlate with significant postoperative functional improvement in many patients with cataract,²⁸ testing only at distance with high-contrast letters viewed in dark-room conditions will underestimate the functional problems in common real-life situations. These may include reading, especially in poor-contrast environments, day-time or night-time glare conditions, halos and starbursts at night, and impaired optical quality causing monocular diplopia and ghosting.²³ Because preoperative 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.^{4,30}

Studies have indicated that measures of functional impairment related to vision provide valid and reliable information that is not reflected in the measurement of visual acuity.^{24,31-33} 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 correlate more strongly with functional improvement and satisfaction with vision after cataract surgery than does Snellen visual acuity.²³

Two main categories of validated questionnaires for measuring function exist: those that measure general health status (e.g., Short Form-36,¹⁹⁰ Sickness Impact Profile,¹⁹¹ and Quality of Well-Being Scale³³) and those that are vision-specific measures. Questionnaires that measure general health status are less strongly correlated with improvement following cataract surgery than are disease-specific measures.^{33,192} Vision-specific instruments developed or used for cataract evaluation include one by Bernth-Peterson,¹⁹³ the Visual Activities Questionnaire,²¹ the ADVS,³¹ the VF-14²³ and modified versions (e.g., VF-8R),¹⁹⁴ the National Eye Institute Visual Function Questionnaire (NEI-VFQ),^{195,196} and the Catquest-9SF.²⁵ These questionnaires have been utilized as research tools to provide a standardized approach to assessing visual function, which can be analyzed and compared across time periods and populations. Questionnaires used alone 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.¹⁹⁷ However, visual function questionnaires can contribute to the overall evaluation of a patient who has a cataract, and they 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 who are least aware of their visual impairment typically have fairly symmetric cataract formation.

Ophthalmic Evaluation

The comprehensive evaluation (history and physical examination) includes those components of the comprehensive adult medical eye evaluation¹⁹⁸ specifically relevant to the diagnosis and treatment of a cataract as listed below.

- ◆ Patient history, including the patient's 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, 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 visual acuity (with refraction when indicated)
- ◆ External examination (eyelids, lashes, lacrimal apparatus, orbit)
- ◆ Examination of ocular alignment and motility
- ◆ Assessment of pupillary function
- ◆ Measurement of intraocular pressure (IOP)
- ◆ Slit-lamp biomicroscopy of the anterior segment
- ◆ Dilated examination of the lens, macula, peripheral retina, optic nerve, and vitreous
- ◆ Assessment of relevant aspects of the patient's mental and physical status

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 correlating slit-lamp biomicroscopy findings with the patient's specific symptoms.

Occasionally, a patient presents with visual symptoms that are disproportionate to the degree of cataract formation. Visual acuity testing alone does not quantify certain visual symptoms, such

as disabilities due to glare and reduced contrast sensitivity.^{193,199-203} In addition, measurements taken in a darkened examination lane with a high-contrast, brightly illuminated target may significantly underestimate the functional problems experienced under a wide variety of lighting and contrast conditions.

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 ambient daylight or from oncoming automobile headlights at night. Visual acuity in some patients with cataracts may be normal or near normal when tested in a dark examination room, but when these patients are retested together with a source of glare, visual acuity (or contrast sensitivity) may drop significantly.²⁰⁴

Contrast sensitivity testing measures the eye's ability to detect subtle variations in shading by using figures that vary in contrast, luminance, and spatial frequency and is a more comprehensive but 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 not appreciated by Snellen visual acuity testing alone.^{199-202,205,206} 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.^{207,208} This may explain the symptoms reported by some older individuals with a mild lens opacity and reasonably good best corrected visual acuity (BCVA).

Biomicroscopic and ophthalmoscopic examinations of the macular region do not necessarily predict macular function when the macula is abnormal. Potential acuity testing attempts to predict the visual acuity following cataract surgery, and it may contribute helpful adjunct information in these situations.^{209,210} Potential acuity tests are most accurate in patients with mild to moderate cataracts in the absence of concomitant retinal disease. However, these tests perform less reliably in patients with cataract who present with visual acuity worse than 20/100.^{209,211-213}

Subjective potential acuity tests can be divided into two categories. The Guyton-Minkowski Potential Acuity Meter, laser interferometer, and scanning laser ophthalmoscope project an image onto the retina through relatively clear regions of the lens, and the patient is asked to identify the letters or pattern.²¹⁴ Other tests such as the Retinal Acuity Meter (formerly the Illuminated Near Card) and potential acuity pinhole require the patient to read a brightly illuminated near card through a trial frame that combines their near eyeglass correction with a pinhole.^{209,213,215,216} The near-card pinhole methods are simpler and less expensive and may give better accuracy in the absence of ocular comorbidity than the technology-dependent Guyton-Minkowski Potential Acuity Meter and scanning laser ophthalmoscope. When the preoperative distance acuity is 20/100 or better, the Retinal Acuity Meter may be more likely to predict the postoperative visual acuity in the presence of ocular comorbidity correctly.^{213,215}

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

Specular microscopy and corneal pachymetry have been used to evaluate patients with known preoperative corneal disease in an effort to determine whether the cornea is likely to remain clear following cataract surgery. These tests are generally not needed, but 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. However, several studies suggest that specular microscopy has relatively low accuracy in predicting whether the cornea will remain clear following cataract surgery.^{217,218}

Although not routinely necessary, assessment of the ocular surface with corneal topography may be useful to determine whether irregularities in corneal power and shape are contributing to visual impairment. Additionally, corneal topography is helpful in the assessment and management of regular and irregular astigmatism.

Optical coherence tomography (OCT)^{219,220} and diagnostic and fluorescein angiography may be helpful prior to cataract surgery for confirming normal foveal architecture or for identifying the presence of comorbid disease, even when the foveal center and immediately surrounding areas appear normal on direct examination.

B-scan ultrasonography is appropriate when a dense cataract precludes adequate visualization of the posterior segment or to confirm the presence of a 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

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 where appropriate.

At the present time, the best available evidence does not support a benefit from nutritional supplementation in preventing or delaying progression of cataracts; therefore, treatment with supplements is not recommended (see Appendix 2).¹⁴¹ Currently, there are no pharmacological treatments known to eliminate existing cataracts or retard their progression and, if asked, ophthalmologists should advise patients that nutritional supplements and pharmacological treatments are of no proven efficacy.

Patients may reduce their risk of cataract development or progression by modifying their exposure to risk factors, such as through cessation of smoking and tobacco use or improved control of diabetes.

Studies have found that a physician's advice to quit is an important motivator in attempting to stop smoking.²²¹⁻²²⁴ Cataracts, therefore, give the ophthalmologist an opportunity to discuss and promote not only the ocular benefits but also the 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^{99-102,151,225} and may wish to discuss alternative medications with their primary care physician. Brimmed hats and ultraviolet-B blocking sunglasses are reasonable precautions to consider recommending, but there is no interventional trial that proves that such intervention will reduce the risk of cataract formation.^{132,226}

Surgical Management

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:

- ◆ 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 (phacolysis, phacoanaphylaxis)
- ◆ The lens induces angle closure (phacomorphic)

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 has the following responsibilities:^{227,228}

- ◆ To examine the patient preoperatively (see Ophthalmic Evaluation)
- ◆ 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 surgical experience²²⁹
- ◆ To review the results of the presurgical evaluation with the patient or the patient's surrogate decision maker
- ◆ To formulate a surgical plan, including selection of an appropriate IOL
- ◆ To formulate postoperative care plans and inform the patient or the patient's surrogate decision maker of these arrangements (setting of care, individuals who will provide care)
- ◆ To answer the patient's questions about the surgery and care, including associated costs

The best interest of the patient is served by having the operating ophthalmologist perform the preoperative evaluation, because this will allow the surgeon to formulate the surgical plan and to establish a relationship with the patient prior to surgery. 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.^{227,228}

All patients undergoing cataract surgery should have a history and physical examination relevant to the risk factors for undergoing the planned anesthesia and sedation and as directed by a review of systems. 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.²³⁰

Laboratory testing as indicated by the findings in the history and physical examination is appropriate.²³¹ The Study of Medical Testing for Cataract Surgery demonstrated that perioperative morbidity and mortality were not decreased by the use of routine medical testing. Preoperative testing should be recommended as appropriate for particular medical problems for a given surgical candidate, not as a routine practice.^{231,232}

Biometry and Intraocular Lens Power Calculation

The 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. 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.²³³⁻²³⁵ When the immersion technique is used, the ultrasound probe does not come in direct contact with the cornea, making the measurements more consistent.

Optical biometry is a high-resolution noncontact method for measuring axial length that uses a specialized light source rather than ultrasound. It is significantly more accurate and

consistent than contact (applanation) A-scan biometry.^{233,236,237} Optical biometry was initially considered to be comparable to immersion A-scan biometry, but it has since been shown to produce improved refractive outcomes; the patient's spherical equivalent is more likely to be closer to the target refraction.²³⁸⁻²⁴⁰ Optical biometry has also been shown to give user-independent results.²⁴¹ 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. Because optical biometry measures the refractive axial length rather than the anatomic 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.²⁴² Additionally, it is easier to use optical biometry than ultrasound when the patient has silicone oil in the posterior segment.^{243,244} Despite recent advances in optical biometry that now allow the measurement of axial length through increasingly dense cataracts,²⁴⁵ A-scan biometry may be necessary to measure the axial length in certain cataracts or when patients are unable to fixate properly.^{246,247} 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 through corneal topography. Following keratorefractive surgery, the determination of central corneal power is particularly difficult (see Cataract Surgery Following Refractive Surgery section). All devices that measure corneal power by standard methods are unable to accurately determine the central corneal power following keratorefractive surgery. The use of standard keratometry in this setting without a compensatory adjustment will typically result in an unanticipated refractive outcome.

Recent-generation theoretical IOL power calculation formulas such as Hoffer Q, Holladay, and SRK/T should be used in the IOL selection process.²⁴⁸⁻²⁵³ Some newer generation formulas, such as Haigis, Holladay 2, and Olsen, 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. 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 formulae, these numbers are generally considered to be only a recommendation and may not correspond to the biometry method being used. The eventual 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. Depending on the manufacturer, a limited number of extended-range high plus and high minus IOL powers is available. For the patient with extreme myopia, very low-power IOLs that 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.²⁵⁴ For a patient with extreme hyperopia requiring an IOL power in excess of the available range, piggybacking two posterior chamber IOLs has been used.²⁵⁵ When this is required, it is preferable to use lens optics of different materials in different locations rather than inserting both IOLs within the capsular bag. This will reduce the risk of interlenticular (between the IOLs) membrane formation.^{256,257} 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.²⁵⁸ Refractive results with piggybacking IOLs have been favorable in two small case series.^{259,260}

Anesthesia

Cataract surgery may be performed using a variety of anesthesia techniques that include general and local (regional) anesthesia (e.g., retrobulbar, peribulbar, sub-Tenons injection, topical, and intracameral). 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 among anesthesia techniques.²⁶¹⁻²⁶⁸

Local (regional) anesthesia is generally preferred, with or without sedation/analgesia. General anesthesia may be utilized if needed for those 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.^{261,265-269}

Anesthesia techniques with needle injections may be associated with complications such as strabismus, globe perforation, retrobulbar hemorrhage, intravascular or subarachnoid injection, and macular infarction not seen with topical, blunt cannula, and other non-needle injection techniques.^{261,265-269} The risk of globe perforation by needle injection is increased with axial myopia and following scleral buckle placement.

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 may make it less frightening.^{270,271}

Intravenous access is generally recommended to treat potential adverse events when sedation/analgesic agents are administered.²⁷² However, given the trend toward topical anesthesia and reduction or elimination of intravenous analgesia/sedation, IV access may not be routinely necessary. Monitoring during administration of anesthesia and surgery generally includes electrocardiogram, pulse oximetry, blood pressure, and respirations. These should be performed by personnel (other than the operating ophthalmologist) qualified to monitor and manage the patient's status. One study found that a patient's medical history, laboratory values, and electrocardiogram were not predictive of the need for intervention by anesthesia professionals, and intervention was required in 37% of all cataract cases.²⁷³ However, this study, in which all patients received a peribulbar block, did not document that any of the interventions by anesthesia personnel affected cataract surgery outcomes. In another study, monitored anesthesia care for 1957 cataract surgery cases was provided by registered respiratory practitioners who were trained as anesthesia assistants and who used topical anesthesia with or without IV sedation. Two studies reported on their experiences using registered nurses or registered respiratory practitioners trained as anesthesia assistants.^{274,275} Anesthesiologist consultation was required in 4% to 8% of the cases, and actual intervention by the anesthesiologist happened in less than 1% of the cases.

The review of studies using local anesthesia in cataract surgery found weak evidence to support the benefits of IV or intramuscular sedation or analgesia to improve pain relief, anxiety, or patient satisfaction.²⁶¹ 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.²⁶² 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.^{263,276,277} The evidence is inconclusive on the value of oral anxiolytic medications to reduce the patient's anxiety levels when given before cataract surgery.²⁷⁶⁻²⁷⁸

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 and the preference of the patient, the anesthesia professionals, and the surgeon.

Infection Prophylaxis

Prevention is of great importance 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 emerging 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 increased occurrence of acute endophthalmitis more than a week after surgery.⁵²⁻⁵⁵

Historically, the expected incidence of sporadic endophthalmitis has been between 0.5 and 1 case per thousand of routine cataract procedures. However, since 1994, an increased rate of postcataract surgery infections has been reported, while the incidence of infection after other anterior segment procedures has been on the decline.^{64,279-281} It has been proposed that the increased infection rates correspond 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.²⁸²⁻²⁸⁹ On the other hand, four large case series found no greater likelihood of infection with corneal versus other types of incisions.^{50,290-292} 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.⁶⁵ Other factors associated with increased rates of endophthalmitis include intraoperative rupture of the posterior capsule, vitreous loss, prolonged surgery, immunodeficiency, active blepharitis, lacrimal duct obstruction, inferior incision location, male gender, and older age.^{59,65,66,291,293-296}

Three retrospective studies suggest a greater endophthalmitis incidence with a planned extracapsular cataract extraction (ECCE) when compared with cataract surgery by phacoemulsification.²⁹⁷⁻²⁹⁹ However, assuming proper incision closure, there is no 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.^{59,284,299,300} 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.^{301,302} As a corollary, it has been demonstrated that antibiotics reduce the tendency for microorganisms to adhere to the surface of IOLs.^{303,304} 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.³⁰⁵

While very occasional clusters of infections may be induced by contaminated surgical products³⁰⁶⁻³⁰⁹ or contaminated operating room environments,^{310,311} it has been established that the patient's periocular flora is the source of the microbes responsible for most cases of sporadic postoperative infection.³¹² Presumably the risk for endophthalmitis can be lessened by reducing the number of microbes on the ocular surface, by reducing the opportunity for microbes to reach the intraocular environment during or after surgery, or by eliminating those organisms that may have reached the eye intra- or postoperatively.

In accord with those concepts, prophylactic strategies that have been used include applying topical antibiotic eyedrops 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 eyedrops after surgery.

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.³¹³⁻³¹⁵ Lower concentrations of povidone iodine are less effective in reducing conjunctival

bacterial colony counts.³¹⁶ The presence of lidocaine gel prior to povidone iodine instillation appears to diminish its antimicrobial efficacy.³¹⁷

Systemic antibiotics are rarely used; however, it has been shown that 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 beneficial.³¹⁸⁻³²¹

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 eyedrops on the incidence of endophthalmitis after phacoemulsification was halted early because of demonstration of a beneficial effect of intracameral cefuroxime. With 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.³⁰⁰ 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.^{59,322} Five other retrospective studies in Europe have reported that intracameral injection of cefazolin or cefuroxime reduced postcataract endophthalmitis.^{51,299,323-326}

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. Although efficacy has not been demonstrated, several studies support the safety of intracameral moxifloxacin injection for endophthalmitis prophylaxis.³²⁷⁻³²⁹

Mixing noncommercially formulated antibiotic solutions for intracameral use carries the risk of dilution errors with potential toxicity.³³⁰

In contrast to 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.³³¹ Compared with an intracameral bolus, antibiotic in the infusate has the theoretical disadvantage of achieving less predictable intraocular antibiotic concentration and duration.⁵⁷

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 intraocular toxicity from subconjunctival leakage through the incision with the potential for macular infarction when aminoglycosides are used.^{66,332,333}

Retrospective studies suggest that topical antibiotic prophylaxis may be effective and a survey (1312 respondents; 33% response rate) from the American Society for Cataract and Refractive Surgery (ASCRS) members found that they were used by 88% of respondents preoperatively and 98% of respondents postoperatively.³³¹ With respect to timing, other studies support the practice of initiating topical antibiotics immediately following surgery rather than waiting until the first postoperative day.⁶¹⁻⁶⁵

Topical gatifloxacin and moxifloxacin 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.³³¹ However, 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.³³⁴

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).

Use of a 5% solution of povidone iodine in the conjunctival cul de sac is recommended to prevent infection.^{314,335}

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. Because of the lack of and impracticality of sufficiently large prospective clinical trials, there is insufficient evidence to recommend a specific antibiotic drug or method of delivery for endophthalmitis prophylaxis.

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.⁶⁵ It would appear that antibiotic use on the day of surgery is important rather than waiting until the next day. Any additional prophylactic antibiotic strategy in the perioperative period is up to the ophthalmologist to determine.

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 and severe anterior chamber cell and flare, fibrin, and hypopyon. Sequelae may include an atonic pupil, secondary glaucoma, and corneal decompensation.³³⁶ 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 taken to rule out infection, and antibiotic treatment should be initiated.³³⁷

There is a large variety of factors that are associated with TASS, but it is often difficult to prove the etiology.³³⁶ Documented causes include heat-stable gram-negative endotoxin from municipal water supplies, use of chemical detergent and enzyme for cleaning of instruments, ointment seepage through clear corneal incisions, denatured ophthalmic viscosurgical device (OVD) residue, solutions of nonphysiologic pH and osmolality, and IOL polishing compounds. Dilution error resulting in a very high dose of intracameral antibiotic has also been documented as a cause of TASS.³³⁰

One published study reviewed 1276 TASS cases that were reported either by questionnaire (77 centers) or by site visit (54 centers) from 2005 to 2009.⁶⁸ 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 the cleaning and sterilization of instruments.⁶⁸ A recent 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.⁶⁷

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 implant) describe the steps to be taken before and on the day of surgery, and they delineate the roles and responsibilities for different members of the health care team.⁷⁷⁻⁸² The Wrong-Site Wrong-IOL Checklist (see Appendix 3) is an example of how to document in the surgery chart that all the appropriate steps have been taken in preventing wrong-site and wrong-surgery events. Adherence to presurgical protocols or checklists has demonstrated a reduction in adverse surgery events and should be implemented.^{78,81}

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 needed to perform cataract surgery.

The preferred method to remove a cataract is extracapsular extraction, most commonly by phacoemulsification. In the United States, the majority of cataract surgeries are performed by phacoemulsification. The 2010 Leaming Survey highlighted that many respondents use topical anesthesia with intracameral lidocaine, clear-corneal incisions, and a no-suture technique.³³⁸

In a randomized trial of ECCE and small-incision phacoemulsification, there were fewer surgical complications, visual acuity was significantly better, and there was a lower incidence of posterior capsular opacification (PCO) in the phacoemulsification group during the 1-year follow-up period.³³⁹

An adjunctive modality for cataract extraction is the femtosecond laser,³⁴⁰ which can be used to construct corneal incisions,³⁴¹ perform the anterior capsulotomy, and fragment the nucleus. At present, there are few peer-reviewed studies that provide evidence on the relative benefits and disadvantages of femtosecond laser.

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 astigmatism³⁴²⁻³⁴⁵
- ◆ Thorough removal of all lens material³⁴⁶
- ◆ Minimal or no trauma to the corneal endothelium, iris, and other ocular tissues^{347,348}
- ◆ 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 fluidically stable anterior chamber³⁴⁹
- ◆ Use of an OVD to protect the corneal endothelium, manipulate tissues, and maintain adequate working space during surgery³⁵⁰
- ◆ Capsulorrhexis,³⁵¹ which is a continuous curvilinear capsulotomy that facilitates 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 PCO for some IOL designs.³⁵²
- ◆ Hydrodissection,³⁵³ which reduces zonular stress during phacoemulsification by mobilizing the nucleus and epinucleus. By facilitating thorough cortical aspiration, hydrodissection also helps to retard PCO.^{354,355}
- ◆ Nuclear disassembly and emulsification using techniques such as divide and conquer³⁵⁶ or chopping³⁵⁷ to allow nuclear removal through a capsulorrhexis and small incision³⁵⁸
- ◆ Thorough removal of remaining epinucleus and cortex³⁴⁶
- ◆ 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 sulcus⁶⁹ (with or without sutures or capsulorrhexis capture³⁵⁹) or anterior chamber
- ◆ Removal of the OVD to minimize postoperative IOP elevation³⁶⁰
- ◆ Assurance of a watertight incision using sutures if the incision size and architecture alone do not produce a secure, self-sealing wound^{59,286,342,361,362}

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.³⁶³⁻³⁶⁵

When feasible, small-incision surgery is generally preferred for a number of reasons.³⁶⁶ 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.^{367,368} Finally, smaller incisions induce less unwanted astigmatic change than larger incisions^{366,369-373} and result in earlier and greater long-term stability of the refraction.³⁷⁴⁻³⁷⁶

Large-incision manual ECCE may be preferred for certain complicated eyes, such as those with mature nuclei, weak zonules, or a higher risk of corneal decompensation.

Intraocular Lenses

Intraocular lens implantation is the method of choice to correct aphakia, unless there are specific contraindications.³⁷⁷ Posterior chamber IOL implantation in the capsular bag is the optimal method in most cases.³⁷⁸

Cataract surgeons can choose from a wide variety of posterior chamber IOL styles and materials to find the appropriate one for their patients' needs. Intraocular lens optic size and shape, optic and haptic configuration, optic edge design,³⁷⁹⁻³⁸² optic and haptic materials,³⁸³⁻³⁸⁵ and chromophore content are engineered to give 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 of their ability to be implanted through smaller incisions. Foldable IOLs can be 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 the IOL optic when the IOL is in an aqueous environment. They are observed in all types of IOLs but have been mainly associated with some hydrophobic acrylic IOLs. Although the impact of glistenings on postoperative visual function and the evolution of glistenings in the late postoperative period remain controversial, IOL explantation has rarely been reported.³⁸⁶ 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 attributes 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. All foldable IOL materials are associated with minimal giant-cell foreign-body reaction.³⁸⁷⁻³⁸⁹ Foldable IOLs can be inserted with either forceps or with injection devices; in some cases IOLs come preloaded in insertion devices.^{390,391} 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.³⁰⁵

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. Options include implanting either an anterior chamber IOL or a posterior chamber IOL positioned in the ciliary sulcus.^{69,392-395} Suturing of posterior chamber IOL haptics to the iris or sclera may be necessary in the absence of sufficient residual capsular support.^{69,392-395} Certain IOL designs, such as accommodating or plate haptic IOLs, require capsular-bag fixation. In general, single-piece acrylic IOLs should not be implanted in the ciliary sulcus because of associated risks such as IOL decentration and posterior iris chafing that cause transillumination defects, pigment dispersion, elevated IOP, recurrent hyphema, and inflammation.⁶⁹

Optimal characteristics of a sulcus-fixated posterior chamber IOL include sufficient overall length, posterior haptic angulation, and the absence of sharp anterior optic edges.⁶⁹ With no posterior capsular barrier, silicone IOLs may compromise surgical visibility should silicone oil or expansile gas ever be required.^{70,71} Anticipating a more anterior location of the optic, the sulcus IOL power should be decreased by 0.5 diopters (D) to 1.0 D relative to that calculated for capsular-bag fixation (but decreased less with capsulorrhexis capture of the optic).^{72,73} The latter strategy reduces reliance on adequate haptic length to provide optic centration and stability.⁷⁴ 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.^{75,76}

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.^{69,392-395} Risks of these approaches include improper anatomic placement and suture breakage.³⁹⁶⁻⁴⁰⁰ 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, while rotation and movement of an IOL that is too short may induce chronic inflammation, cystoid macular edema (CME), and corneal endothelial damage.⁶⁹ A peripheral iridectomy should be used to prevent the risk of pupillary block associated with an anterior chamber IOL. Multiple studies support the efficacy of all three methods of IOL fixation—anterior chamber and iris or scleral sutured posterior chamber—in the absence of adequate capsular support.^{69,392-395}

Optical and Refractive Considerations

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

Aspheric IOLs have been designed to reduce or eliminate the spherical aberration of the eye. Multiple clinical studies have demonstrated a pupil-dependent reduction in ocular spherical aberration with aspheric IOLs, and some of these studies have also revealed varying degrees of superior contrast sensitivity with these IOLs relative to spherical IOLs.^{46,401-413} However, the potential advantages of aspheric IOLs remain controversial, particularly in the areas of functional benefit⁴¹⁴⁻⁴¹⁶ and depth of focus.^{188,417} The potential advantages and disadvantages can be affected by pupil size,⁴¹⁸ IOL tilt⁴¹⁹ and decentration,⁷⁵ and whether the spherical aberration of the IOL and the patient's cornea were custom matched.^{420,421}

Toric IOLs reduce eyeglass dependence after cataract surgery due to corneal astigmatism. Between 15% and 29% of cataract patients have more than 1.5 D of keratometric astigmatism.^{422,423} Toric IOLs have been shown to decrease eyeglass dependence compared with nontoric monofocal IOLs.^{424,425} In addition, they may offer better predictability and stability of correction compared with incisional astigmatic keratotomy.^{426,427} For a toric IOL to be effective, the axis and magnitude of keratometric astigmatism must be accurately measured, and the IOL must be accurately and permanently aligned.⁴²⁸ Toric IOL axis misalignment may reduce the desired refractive effect or may even worsen the overall astigmatism. Because toric IOLs do not correct irregular astigmatism, they should not be used in patients who will require a rigid contact lens.

Monovision- and presbyopia-correcting IOL implants are used in an attempt to improve quality of life by reducing eyeglass dependence after cataract surgery.⁴²⁹ For each of these options, patient selection is critical, because 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 option can be selected. Patients should be informed of the potential compromise in quality of vision associated with these choices.^{430,431}

Monovision is a condition in which one eye is corrected for distance vision and the fellow eye is corrected 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 a cataract population that desired independence of correction with eyeglasses.⁴³² 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.⁴³³ Patients with a history of monovision success are particularly well suited for this modality.^{434,435}

Presbyopia-correcting IOLs can be classified as multifocal or accommodative (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. 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.⁴³⁶ Optical effects of multifocal IOLs may include reduced contrast sensitivity, halos around point sources of light, and glare.⁴³⁷ 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.⁴³⁸ 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. Therefore, the candidacy of patients with amblyopia or abnormalities of the cornea, optic disc, and macula for a multifocal IOL must be carefully considered.

In an attempt to mimic human accommodation, accommodative 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 with multifocal IOLs.^{439,440}

Outcomes

Results of multiple large studies of cataract surgery have repeatedly demonstrated positive outcomes. The ASCRS National Cataract Database reported that at 3 months postoperatively 85.5% of all patients had a 20/40 or better BCVA, 57.2% of patients had 20/25 or better postoperative BCVA, and 74.6% of patients were within ± 1.0 D of target spherical equivalent. Based on 5788 responses, the mean visual function index score at 3 months postoperatively was 70.3% compared with 55.0% preoperatively. (The score is based on a scale of 0 to 100, with 0 indicating an inability to perform any of the activities.) The European Cataract Outcome Study for 1999 reported that 89% of patients achieved a postoperative visual acuity of 0.5 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.⁴⁴¹ 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 92.2% of patients and improvement in VF-14 in over 90% of patients.⁴⁴² 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.⁴⁴²

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 ocular comorbidity. More recently, a large multicenter study in the United Kingdom showed results from cataract surgery of 20/40 or better in 94.7% of eyes with no ocular comorbidity.⁴⁴³

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%.⁴⁴⁴⁻⁴⁴⁹ If eyes with ocular comorbidities are excluded, the reported range of patients with postoperative BCVA of 20/40 or better was 86% to 98%.⁴⁴⁷⁻⁴⁵⁰

The Cataract Patient Outcomes Research Team (PORT) study identified preoperative characteristics that were independent predictors of greater improvement after surgery: younger age, less comorbidity, higher cataract symptom score, and worse preoperative VF-14 (measure of visual function) score.³⁰ These investigators found that patients younger than 65 showed greater improvement than those over 65 and that patients with more severe symptoms and more severe dysfunction showed greater improvement than

those with less severe symptoms or dysfunction.³⁰ Preoperative Snellen visual acuity was found to be unrelated to the likelihood of improvement in symptoms or self-reported visual function after cataract surgery in several studies.^{30,451,452} 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.⁴⁵¹ Even patients with diabetes and age-related macular degeneration (AMD), however, showed significant improvements after cataract surgery, albeit at a lower magnitude than patients without these conditions.⁴⁵³⁻⁴⁵⁵ Although these studies have shown that benefits are greater in patients of younger age, the improvement in quality of life for those 75 years old 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 preoperative Snellen acuity better than or equal to 20/50.²⁹ Even in eyes with 20/20 preoperative Snellen acuity, cataract surgery improved patients' self-reported visual impairment. Neither the preoperative best corrected high-contrast Snellen distance acuity nor the 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 acuity in isolation will not accurately predict who will benefit from surgery.

Complications of Cataract Surgery

Although there are numerous complications that can occur after cataract surgery, those resulting in permanent loss of vision are rare. Major complications that are potentially sight-threatening include infectious endophthalmitis, TASS, intraoperative suprachoroidal hemorrhage, CME, retinal detachment, persistent corneal edema, and IOL dislocation.

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 2:1.⁴⁵⁶ Six subsequent studies of adverse perioperative outcomes from cataract surgery are summarized in Table 2. Greenberg et al⁴⁵⁷ 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 3.3% and the rate of retained lens fragments was 1.7%.

Stein et al⁴⁵⁸ 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 the overall rate of complications after phacoemulsification as 8.7%.⁴⁵⁹ Of the complications reported, 2.4% were considered major, including vitreous loss (1.1%), lens drop (0.1%), iris trauma (1.2%), retinal detachment (0.2%), and endophthalmitis (0.1%). Other nonmajor complications included wound leak (1.1%), prolonged corneal edema (0.7%), uveitis (1.1%), and persistent elevated IOP (0.3%).

Specific complications following cataract surgery are discussed below.

Incision Complications

An incision that is not watertight can lead to several complications, including postoperative wound leak, hypotony, and endophthalmitis.⁶⁵ An incision that is too small can decrease the ability to cool the ultrasonic phacoemulsification needle and increase the risk of wound

TABLE 2 COMPLICATION RATES FROM SELECTED STUDIES OF CATARACT SURGERY

	Cataract PORT, 1994 ⁴⁵⁶	Schein et al, 1994 ⁴	NEON, 2000 ⁴⁴²	Zaidi et al, 2007 ⁴⁵⁹	Jaycock et al, 2009 ⁴⁴³	Greenberg et al, 2011 ⁴⁵⁷	Clark et al, 2011 ⁴⁶⁰
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 survey⁴⁶¹ of Veterans Health Administration facilities found that phacoemulsification was performed in approximately 95% of extracapsular cataract surgeries.

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

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

|| Postoperative information was not available for all study patients.

burn. An incision that is too large will cause leakage of fluid from the wound and destabilize the anterior chamber. Wound burn (ultrasound stromal thermal damage) occurs at 60° C or higher.⁴⁶² A recent survey representing 419 cases of wound burn, showed an incidence of 0.043%.⁴⁶³ In a multivariate analysis, the factors significantly associated with this problem in order of decreasing significance were lower surgical volume, the surgical technique, and the OVD used.⁴⁶³

An incision that is not self-sealing at the end of the surgery may require sutures or adhesive for proper closure. The risk of perioperative wound leak (e.g., risk increased with eye rubbing, poor scleral rigidity) is another consideration for the use of sutures or eye protection postoperatively. Sutures can induce postoperative astigmatism, the magnitude of which is dependent on their location and tension.^{365,464}

Iris Complications

Iris prolapse can result from intraoperative floppy iris syndrome (IFIS) or a poorly constructed incision. Other causes of surgical iris trauma may include iris aspiration or agitation with the phacoemulsification tip, sphincterotomies, and excessive stretching or manipulation with expansion devices and instruments. The sequelae of such trauma may include iridodialysis, hyphema, transillumination defects, traumatic mydriasis, and an irregular, atonic, or misshapen pupil. Sphincter necrosis can occur perioperatively as a result of endophthalmitis, TASS, or excessive IOP elevation.

Corneal Complications

Improper instrument entry into the anterior chamber can lead to Descemet's membrane tears or detachment.⁴⁶⁵ A small tear can be repaired by repositioning and tamponading the flap of Descemet's membrane with an air bubble. The corneal endothelium is susceptible to damage from any mechanical injury and from prolonged ultrasonic power during nuclear removal. It can also be damaged by intraocular solutions with a nonphysiologic osmolarity or pH, or by chemical insult from toxic contaminants or improperly formulated intraocular solutions and medications.^{68,336} Prolonged elevated IOP can lead to further endothelial decompensation and corneal edema.

Prolonged Inflammation

There are several etiologies for abnormally prolonged postsurgical inflammation. Persistent iritis has been associated with retained lens fragments,⁴⁶⁶ history of uveitis,⁴⁶⁷ and a subacute infection with *Propionibacterium acnes*.⁴⁶⁸ Insufficient administration of postoperative anti-inflammatory medication may also be a contributory cause.

Endophthalmitis

In studies of cataract surgery in the United States, the reported incidence rates of postoperative endophthalmitis are 0.04% to 0.2%.^{4,279,291,457} The incidence of endophthalmitis reported in other English-language peer-reviewed literature ranges from 0.02% to 1.16%.^{60,296,298,321,442,456,458,460,469-472} *Staphylococcus epidermidis* was the most common pathogen.^{469,470} Risk factors for developing endophthalmitis after cataract surgery include posterior capsular rupture (up to 10-fold increase),^{65,66,291,296,472} older age,²⁹⁶ relative immunodeficiency,²⁹¹ resident-performed cataract surgery,⁶⁶ wound leak on first postoperative day,⁶⁵ inferior incision location,²⁹¹ longer length of surgery,⁴⁷³ topical anesthesia,⁴⁷³ and the use of topical lidocaine gel before povidone iodine.²⁹¹

The type and size of incision (clear corneal or sclera) has been implicated as a possible factor in the development of endophthalmitis. Several articles found no conclusive evidence for an association of clear corneal incision and endophthalmitis.^{291,474,475}

Patients may present with complaints of decreased vision, pain, redness, new floaters, and eyelid edema.^{476,477} Although historically the onset of symptoms was considered to occur during the first postoperative week,^{49,478,479} newer studies report a delayed onset of up to 13 days.^{291,480} Common findings include conjunctival injection, corneal edema, anterior chamber inflammation, hypopyon, and vitritis.^{476,477}

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 chamber should be tapped for evaluation of possible pathogens, followed by an intravitreal injection of antibiotics. The Endophthalmitis Vitrectomy Study (EVS) recommended an intravitreal tap plus injection of antibiotics alone 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 with a pars plana vitrectomy and antibiotics.⁴⁹

Posterior Capsular Tear or Zonular Rupture

There is great variability in reported rates of posterior capsular or zonular ruptures. They range from 1.6% up to 9% in high-risk patients with previous pars plana vitrectomy.^{442,443,481-483} Risk factors for posterior capsular tears and vitreous loss include older age, male gender, glaucoma, diabetic retinopathy, brunescence or white cataract, inability to visualize the posterior segment preoperatively, pseudoexfoliation (exfoliation syndrome), small pupils, axial length greater than 26 mm, use of systemic sympathetic alpha-1a antagonist medication, previous trauma, inability of the patient to lie flat, and resident-performed cataract surgery.^{484,485} Intraoperative risk factors include loose zonules, need for capsular stain, and miosis.⁴⁸⁵

The factors listed above are the known risk factors. However, posterior capsular and zonular complications can sometimes 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%.^{443,456} If there is vitreous loss with posteriorly dislocated lens fragments, it is recommended that the surgeon perform an anterior vitrectomy, with stable placement of an appropriately sized and designed IOL, if available.

The use of injected triamcinolone has been reported to aid in visualization of residual vitreous.⁴⁸⁶ One study found that a large number of IOLs placed during primary surgery complicated by vitreous loss required subsequent explantation. If the appropriate backup IOL power, size, or design is not available, then consideration should be given to leaving the eye aphakic at the time of the primary surgery.⁴⁸⁷ Because of the increased risk of inflammation and elevated IOP, strong consideration should be given to referring patients who have retained lens fragments to a retina surgeon during the early postoperative period.⁴⁸⁸

The most appropriate timing of the secondary pars plana vitrectomy is unclear, but the eye should be carefully monitored for complications, such as elevated IOP and inflammation, as long as retained nuclear fragments are present.⁴⁸⁹⁻⁴⁹¹

Retinal Detachment

Overall rates of retinal detachment range from 0.26% to 4.0%.^{458,460,475,492-497} Risk factors for development of retinal detachment after cataract surgery included axial length more than 23 mm, posterior capsular tear, younger age, male gender, lattice degeneration, zonular dehiscence, retinal detachment in the fellow eye, and postoperative posterior vitreous detachment.^{475,492-497} In one study, the mean interval between cataract surgery and retinal detachment was 39 months,⁴⁹⁷ but the increased risk of retinal detachment in pseudophakic eyes may continue for as long as 20 years.⁴⁹⁸ 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 zero.⁴⁹⁹ There was no statistically significant difference in the probability of retinal detachment after ECCE compared with phacoemulsification.⁴⁹⁸

Suprachoroidal Hemorrhage

Historically, the incidence of suprachoroidal hemorrhage related to large incision cataract surgery was reported to be 0.15% to 0.19%.⁵⁰⁰ and associated with myopia, glaucoma, diabetes, atherosclerotic vascular diseases, and hypertension.⁵⁰¹ Published data on the incidence of

this complication following phacoemulsification are lacking. Anticoagulation with warfarin does not significantly increase the risk of choroidal hemorrhage.⁵⁰²

Clinical signs and symptoms of an intraoperative choroidal hemorrhage include pain, dark shadowing and loss of red reflex, elevated IOP, shallowing of the anterior chamber, and iris prolapse.⁵⁰³ Failure to diagnose the hemorrhage and secure the incision can lead to sight-threatening complications.

Cystoid Macular Edema

Clinically significant CME occurs infrequently after routine uncomplicated small-incision cataract surgery (1.2% to 3.3%)^{443,457,459} and often responds well to medical therapy; 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, epiretinal membrane, prior vitreoretinal surgery, nanophthalmos, retinitis pigmentosa, and a history of pseudophakic CME in the fellow eye. Anatomic diagnosis is frequently made by OCT, which is less invasive 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 and to treat established CME. There is evidence that nonsteroidal anti-inflammatory drugs (NSAIDs) alone or in combination with corticosteroids are more effective than topical corticosteroids alone in preventing and treating acute and chronic CME.⁵⁰⁴⁻⁵¹⁶ The use of intravitreal antiangiogenesis agents for treatment of CME is being investigated, but there is insufficient evidence to support their use at this time.⁵¹⁷

At present, there is no firmly established protocol for preventing postsurgical CME. Although perioperative prophylactic use of NSAIDs for prevention of CME has been advocated for high-risk eyes based on a number of studies, there is no published evidence that the final visual outcome is improved with routine use of prophylactic NSAID.

Intraocular Pressure

There is a recognized tendency for transient elevation of IOP in many eyes during the early postoperative period. Although this rarely causes serious complications, acute postoperative IOP elevation can induce pain, and some eyes may be more susceptible to optic nerve damage or vascular occlusion. The likelihood for IOP elevation increases if excess amounts of the OVD remain in the eye at the close of surgery, and thorough removal of OVD should be attempted.⁵¹⁸ The optimal pharmacological regimen for preventing an immediate postoperative IOP spike is unclear. It appears that topical aqueous suppressants and intracameral carbachol are most beneficial.⁵¹⁹⁻⁵³⁷

Topical corticosteroid use can cause elevated IOP in eyes that are “steroid responders.”⁵³⁸ This is more likely to occur in patients who are younger, highly myopic, or have glaucoma.⁵³⁹ Corticosteroid cessation results in a reduction of the IOP to normal levels, and the IOP should therefore be monitored in eyes being treated with postoperative corticosteroid medication.⁵³⁸

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 of IOL explants, the most common reasons for explantation of foldable IOLs are dislocation or decentration, glare or optical aberrations, incorrect power, and opacification.⁵⁴⁰ The incidence of multifocal IOL explants secondary to glare/optical aberrations is increasing (Mamalis N, Davis D, Maddula S, Ness P. ASCRS/ESCRS survey on foldable IOLs requiring explantation or secondary intervention: 2009 update. Poster presented at: ASCRS Symposium on Cataract, IOL, and Refractive Surgery, April 10, 2010; Boston, MA). Although uncommon, explantation of multifocal IOLs may become necessary if optical side effects are

intolerable. Intraocular lenses may also be damaged during implantation, and it may be necessary for the surgeon to consider intraoperative lens implant exchange.

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 IOL haptics with one haptic in the ciliary sulcus and the other inside the capsular bag. A malpositioned posterior chamber IOL can cause significant visual complaints such as edge glare, higher order aberrations, or IOL inflammation associated with uveal irritation such as iris chafing.⁵⁴¹

Dislocation/decentration has been reported with virtually all IOL materials and models, including both one- and three-piece designs.⁵⁴⁰ This complication is seen most commonly when IOLs are not placed symmetrically within the capsular bag or when there is a situation in which the IOL is placed without an intact capsulorrhexis. The major predisposing factors found for IOL subluxation in one study were secondary implantation, posterior capsular rupture, and mature cataracts.⁵⁴² Plate haptic silicone IOLs can dislocate posteriorly following Nd:YAG capsulotomy and, rarely, spontaneously from capsular contraction. 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.⁵⁴³⁻⁵⁴⁵ The onset is delayed and occurred on an average of 8.5 years following uncomplicated cataract surgery in a study of 86 consecutive cases.⁵⁴⁵ 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.⁵⁴⁵

Glare or optical aberrations are another common reason for explantation. The term dysphotopsia has been used to describe a variety of unwanted visual phenomena encountered by pseudophakic patients.^{546,547} 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 manifest as a dark crescent or curved shadow that can appear similar to a scotoma in the peripheral temporal field of vision.⁵⁴⁸⁻⁵⁵⁰ Initially, positive and negative dysphotopsias were most 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.^{380,551-554} 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.^{548,552,555,556} Complications such as IOL opacification, cracked or damaged optics, and IOL decentration frequently cause dysphotopsias as well. Implantation of a piggyback IOL or reverse optic capture (placing the optic anterior to the capsulorrhexis) appears to reduce the symptoms of negative dysphotopsia. It appears that negative dysphotopsia may be induced at the interface of the capsulorrhexis and the anterior surface of the IOL, suggesting that a reflection of the anterior capsulotomy edge is projected onto the nasal peripheral retina.⁵⁵⁷

Incorrect IOL power may also lead to explantation. It is not possible to predict precisely the final axial position of an implanted IOL. An unwanted refractive result or “surprise” is therefore an inevitable outcome in some patients. The risk is greater with inaccurate keratometry or axial length measurements, such as with uncooperative patients, postrefractive surgery eyes, and atypical anatomic variations such as a staphyloma (see sections on biometry and 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, 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. 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 more recent surveys of IOL explantation.⁵⁴⁰ While IOL calcification was reported with earlier hydrophilic acrylic IOLs, newer hydrophilic acrylic IOLs have been widely used in Europe without a significant incidence of calcification.⁵⁵⁸⁻⁵⁶² Opacification of hydrophilic acrylic IOLs may be misdiagnosed as an opacity of the lens capsule or vitreous, leading to unnecessary surgical intervention.⁵⁶³ More recently, opacification of silicone IOL optics due to calcium deposits following Nd:YAG capsulotomy in eyes with asteroid hyalosis has been reported.^{564,565} For this reason, it may be prudent to avoid silicone IOLs in these patients.

The complication of interphakic 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.^{256,257} 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 has been implanted in the ciliary sulcus following bag placement of the first IOL, unlike when both IOLs are placed within the capsular bag.

As noted earlier, implantation of single-piece acrylic IOLs in the ciliary sulcus are associated with pigment dispersion, iris transillumination defects, elevated IOP, and recurrent inflammation or hemorrhage. 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.

Ocular Comorbidities

Preoperative ocular comorbidities may have a significant effect on the outcome of cataract surgery.^{4,451,566} Many comorbid conditions are associated with the potential for reduced improvement in visual function or BCVA,⁵⁶⁷ and the patient should be adequately informed and counseled during the care process. 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.

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 low.^{568,569}

The status of coexisting diabetic retinopathy, particularly macular edema, may be evaluated by OCT, thereby directing a more vigorous approach to preoperative, intraoperative, and postoperative medical treatment, including the use of intravitreal injections.⁵⁷⁰⁻⁵⁷⁴ Historically, cataract surgery was considered to increase the risk of progression of diabetic retinopathy postoperatively.⁵⁷⁵ Cataract surgery appears to increase the risk of progression of certain types of diabetic retinopathy postoperatively (e.g., from moderate nonproliferative to severe nonproliferative diabetic retinopathy). However, cataract surgery does not appear to increase the risk of progression of adequately treated proliferative diabetic retinopathy or macular edema.⁵⁷⁶ Nevertheless, the visual prognosis for these patients is still uncertain and may be guarded.^{576,577}

Because of the risk of corneal decompensation in the presence of corneal endotheliopathy, the surgeon may consider using retentive OVDs and machine parameters and surgical techniques that reduce cumulative ultrasound time and endothelial trauma.^{578,579}

Pseudoexfoliation (exfoliation syndrome) is commonly associated with a small pupil and weak zonules, which increases the risk of capsular rupture and retained nuclear fragments.⁵⁸⁰ Anterior chamber depth should be assessed preoperatively; an anterior chamber depth of less than 2.5 mm, indicative of zonular weakness, increases the risk of complications fivefold.⁵⁸¹

TABLE 3 SELECTED OCULAR COMORBIDITIES

Comorbidity	Special Considerations (aside from reduced visual potential)
Amblyopia	Reduced visual potential
AMD ⁵⁸²⁻⁵⁸⁴	Reduced visual potential Unrecognized preoperative exudative disease
Diabetic retinopathy ^{576,585-589}	Unrecognized retinopathy Progression of existing retinopathy CSME Poorly dilating postoperative pupil Neovascularization of the iris, neovascularization of the angle, and neovascular glaucoma
Epiretinal membrane ⁵⁹⁰	Reduced visual potential CME
Fuchs' corneal endothelial dystrophy ^{591,592}	Reduced visualization during surgery Prolonged postoperative corneal edema Pseudophakic bullous keratopathy
Glaucoma ^{41-43,593-595}	Elevated postoperative IOP Reduced function of prior filtering surgery
Pseudoexfoliation (exfoliation syndrome) ^{580,581,596-598}	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 ⁵⁹⁹	Amblyopia Intraoperative miosis Traction retinal detachment Loose zonules
Uveitis ⁶⁰⁰⁻⁶⁰⁴	Posterior synechiae Weakened zonules Protein and cellular deposits on the lens implant CME Secondary glaucoma Prolonged postoperative inflammation

AMD = age-related macular degeneration; CME = cystoid macular edema; CSME = clinically significant macular edema; IOL = intraocular lens; IOP = intraocular pressure; PCO = posterior capsule opacification

Because of the risk of late bag-IOL dislocation, Nd:YAG anterior capsule relaxing incisions may be considered for anterior capsule contraction.

The optimal timing of cataract surgery in the presence of uveitis is a function of many factors. Inflammation should be inactive or at its best level of control prior to elective surgery.⁶⁰⁵ Anti-inflammatory medications are often begun prior to surgery, and 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.⁶⁰⁶

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.

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.⁶⁰⁷ A specific OVD may be selected based on its characteristics in cases of corneal endothelial deficiency, shallow anterior chamber, intumescent cataract, and small pupil.⁶⁰⁷

Capsular dyes to stain the anterior capsule may be considered in cases of a white or mature cataract, or where visibility is compromised.^{608,609}

Capsular tension rings can be useful adjunctive devices when weak zonules are present, reducing the likelihood of intraoperative zonular separation and capsular complication,⁶¹⁰ and they may improve postoperative IOL centration.⁶¹¹ In cases of more profound zonulopathy, other options include capsular retractors, a modified capsular tension ring, or capsular tension segment should be considered for scleral suture fixation.⁶¹²

A variety of intraoperative methods have been described to expand the small pupil. Pharmacologic methods include intracameral alpha-1 agonists such as epinephrine or phenylephrine. Mechanical methods include viscomydriasis, release of posterior synechiae, pupil stretching, or microsphincterotomies, iris retractors, or pupil expansion rings.⁶¹³

Intraoperative floppy iris syndrome is a unique small-pupil syndrome that may be associated with iris billowing and prolapse as well as with progressive intraoperative miosis.^{35,36} It is associated with a higher rate of surgical complications, particularly when it is not recognized or anticipated.³⁵⁻³⁹ 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.³⁵⁻³⁷

Systemic Comorbidities

Systemic comorbidities that may be of importance intraoperatively are 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.^{614,615} The occurrence of IFIS is strongly associated with systemic alpha-1 antagonists, whose most common indication is the symptomatic treatment of benign prostatic hyperplasia.^{35,36} The American Urological Association guidelines for the management of benign prostatic hyperplasia recommend that men with planned cataract surgery avoid the initiation of alpha-1 antagonists until their cataract surgery is completed.⁶¹⁶ Discontinuing alpha-1 antagonists preoperatively does not typically prevent IFIS, which may occur long after drug cessation.^{35-38,616} Several retrospective and prospective studies^{35,36,38,39,617} 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, and this has been confirmed in a meta-analysis.⁴⁰

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.

There is insufficient evidence to recommend continuation or discontinuation of anticoagulant or antiplatelet therapy for cataract surgery.^{618,619} Discontinuation of these medications can be associated with medical morbidity. In patients with new coronary stents, premature discontinuation of dual antiplatelet therapy is associated with an increased risk of life-threatening stent thrombosis.⁶²⁰ In a study of 19,283 eyes, the incidence of adverse medical and ophthalmic events was low and statistically indistinguishable in patients who either continued or discontinued anticoagulant or antiplatelet medication use before cataract surgery.⁶²¹ Several uncontrolled case series reported minimal or no complications in patients who were maintained on their anticoagulant or antiplatelet medications prior to cataract surgery.⁶²²⁻⁶³⁰ However, alternatives to retrobulbar injections should be considered for these patients.⁶¹⁹

There are no recommendations from either the American Heart Association^{631,632} or the American Academy of Orthopaedic Surgeons to prescribe systemic antibiotic prophylaxis for patients with artificial heart valves or joint prostheses who are undergoing cataract surgery.⁶³³

TABLE 4 HIGH-RISK CHARACTERISTICS FOR INTRAOPERATIVE AND POSTOPERATIVE COMPLICATIONS

High-Risk Characteristic	Special Considerations
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 ^{634,635}	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 ⁶³⁶⁻⁶³⁸	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 ⁶³⁹⁻⁶⁴³	Anterior chamber depth fluctuation due to reverse pupillary block Difficulty calculating lens implant power especially with posterior staphyloma Decreased ocular rigidity, difficult sealing the wound Increased risk of retinal detachment
Miotic pupil ⁶⁴⁴⁻⁶⁴⁹	Poor visualization Increased risk for capsule tear/vitreous prolapse Increased risk for iris damage and prolapse
Potential need for vitreoretinal surgery	Silicone IOLs may compromise subsequent surgical visibility if posterior segment silicone is needed

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

High-Risk Characteristic	Special Considerations
Prior glaucoma filtration surgery ⁶⁵⁰⁻⁶⁵²	Increased filtration through the bleb during surgery Decreased filtration or bleb failure following surgery Postoperative hypotony Zonular laxity
Prior keratorefractive surgery ⁶⁵³⁻⁶⁵⁵	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 ⁶⁵⁶⁻⁶⁵⁸	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 ⁶⁵⁹⁻⁶⁶¹	Poor visualization Graft rejection or failure IOL power calculation inaccuracy Hyperopic shift in association with DSEK
Prior scleral buckling surgery ⁶⁶²⁻⁶⁶⁴	Change in axial length affects IOL power calculation Conjunctival scarring Increased risk of sclera perforation with injection anesthesia
Posterior polar cataract ⁶⁶⁵⁻⁶⁶⁷	Defective posterior
Posterior synechiae	Intraoperative miosis Prolonged postoperative inflammation Inflammatory deposits on IOLs Iris bleeding
Relative anterior microphthalmos ⁶⁶⁸	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 ^{35,615} and other systemic conditions	IFIS: Poor pupillary dilation and intraoperative miosis Iris billowing and prolapse
White cataract (mature cortical cataract) ^{609,669-671}	Difficulty performing the capsulorrhexis (capsule staining may be helpful) ⁶⁰⁸ Lens intumescence Radial capsulorrhexis tear with extension into posterior capsule
Zonular laxity or dehiscence (e.g., trauma) ⁶⁷²⁻⁶⁷⁴	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's stripping endothelial keratoplasty; IFIS = intraoperative floppy iris syndrome; IOL = intraocular lens

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 traditional procedures such as trabeculectomy and other filtration procedures, drainage devices, and endocyclophotocoagulation.

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.⁴⁸ 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.^{41-44,47}

Generally, a combined phacotrabeculectomy is not as effective as glaucoma surgery alone in lowering IOP.^{48,675} Both one-site and two-site combined procedures appear to provide similar IOP reduction.⁶⁷⁶ Phacoemulsification combined with trabeculectomy provides good IOP control as well as improved BCVA compared with preoperative vision.⁶⁷⁷⁻⁶⁷⁹ A variety of new glaucoma technologies may be combined with cataract surgery. These include canaloplasty,⁶⁸⁰ ab interno trabeculotomy,⁶⁸¹ endocyclophotocoagulation,⁶⁸² and ab interno trabecular bypass microstents⁶⁸³ 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.^{45,684}

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.⁴⁸

Although potentially indicated in eyes with active uveitis, neovascularization, or multiple anterior segment problems, there are disadvantages to performing filtration surgery as a separate procedure prior to 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. While it appears that mitomycin-C may be effective in producing lower long-term IOPs when used with combined procedures, 5-fluorouracil is not.^{48,675,685} Potential vision-threatening complications, such as bleb-related endophthalmitis,⁶⁸⁶⁻⁶⁸⁸ hypotony maculopathy,^{689,690} and late-onset bleb leaks⁶⁹¹ should be considered in the decision to use antifibrotic agents.

The decision about the various surgical treatment options will be based 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. A slit-lamp biomicroscopic examination that demonstrates microcystic edema or stromal thickening, and/or central corneal pachymetry greater than 640 microns,⁵⁷⁸ and/or low central endothelial cell counts by specular microscopy indicate an increased likelihood of corneal failure following cataract surgery. A history of prolonged "foggy vision" upon awakening in the morning often indicates significant endothelial pump impairment. If the lack of evaporation while asleep 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. With borderline endothelial reserve, a more peripheral incision, either temporal clear cornea or corneoscleral, and repeated instillation of OVD may preserve more endothelial cells.⁶⁹²

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 cataract 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.⁶⁹³

Because the postpenetrating keratoplasty corneal curvature is not known at the time of a combined procedure, IOL calculations are less accurate.⁶⁹⁴ Therefore, some surgeons prefer to perform penetrating keratoplasty first, followed by cataract removal later after the corneal graft 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.⁶⁹⁵⁻⁶⁹⁷ In some cases, this approach has the advantage of reducing the amount of time the eye is open during the penetrating keratoplasty surgery. These considerations apply to deep anterior lamellar keratoplasty as well.

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's membrane alone.^{698,699} These procedures can be combined with phacoemulsification and foldable IOL implantation. Among other potential advantages, this approach preserves the anterior corneal curvature and, therefore, should improve IOL power predictability compared with combined penetrating keratoplasty and cataract surgery. Descemet's stripping endothelial keratoplasty has been shown with both OCT and Scheimpflug imaging 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 study⁷⁰⁰ and +1.47 D from the expected biometry result in a second study⁷⁰¹) should be considered if there is significant risk of corneal decompensation following cataract surgery.^{700,701}

Unfortunately, studies to date have shown great variability in this hyperopic shift. One showed a mean decreased corneal power of 1.94 D in comparison to controls,⁷⁰² while another reported a mean outcome of +1.63 D from the expected result looking at combined corneal and cataract surgery (range of 0 to 4.0 D).⁷⁰³ A third showed only a 0.15 D hyperopic shift that was not statistically different from the preoperative refraction.⁷⁰⁴ This great 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 final IOL power accordingly. This will be less of a problem with Descemet's membrane endothelial keratoplasty (DMEK), where the reported hyperopic shift was 0.49 D (range from -1.00 to +1.50).⁷⁰⁵

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, establishing a clear entrance pupil.⁷⁰⁶ 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.⁷⁰⁷

Cataract Surgery and Uveitis

There are special issues to consider when patients with uveitis undergo cataract surgery.^{708,709} Patients with active anterior segment inflammation are at substantial risk for postoperative problems. Patients with anterior or intermediate uveitis are at particular risk of postoperative complications. A major potential problem, especially among patients with pre-existing iris damage or extensive posterior synechiae, is the development of adhesions between the iris and lens capsule postoperatively. Other potential problems include membrane formation, IOL deposits, zonular problems, and CME.

The optimal timing of cataract surgery in the presence of uveitis is a function of many factors. Inflammation should be inactive or at its best level of control prior to elective surgery.⁶⁰⁵ Even if the patient is on chronic anti-inflammatory therapy, additional topical or oral corticosteroids are often prescribed prior to surgery. In one study, pre-operative treatment with oral corticosteroids seemed to decrease the risk of postoperative CME.⁷¹⁰ 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. 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. Surgical procedures may need to be modified to manage pre-existing posterior synechiae, pupillary membranes, 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. 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 pre-operative posterior synechiae). This technique does not seem to increase postoperative inflammation.⁶⁰¹ With capsular bag placement, a large diameter capsulorhexis 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 avoided so as not to exacerbate inflammation and stimulate new 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, periorbital, or intraocular) may be considered. Postoperatively, eyes with uveitis generally require greater frequency and duration of topical corticosteroid treatment and should be monitored closely for complications such as severe iridocyclitis, secondary glaucoma, posterior synechiae, secondary membranes, and CME.⁷¹¹

Cataract Surgery and Vitreoretinal Surgery

Cataract surgery is often necessary prior to, during, or following vitreoretinal surgery. Vitreoretinal procedures, including intravitreal injections, may cause pre-existing cataracts to progress, typically manifesting as increased nuclear sclerosis.⁷¹²⁻⁷¹⁷ Management of such cataracts may be more complex, because capsular defects or weakened zonules may be present.

Combined vitreoretinal and cataract surgery offers the advantage of a single operative procedure and anesthesia, potentially faster recovery, and cost-effectiveness.⁷¹⁸ A wide range of vitreoretinal disorders may be dealt with concomitantly including vitreous hemorrhage, diabetic retinopathy, epiretinal membrane, macular hole, and retinal detachment.⁷¹⁹⁻⁷²¹ 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 employed for more complex cases.⁷²² Secure wound closure is important to permit safe vitreoretinal maneuvers.⁷²³⁻⁷²⁵ Surgeons should consider the nature of the posterior segment pathology and need for visualization when selecting the IOL style, biomaterial, and optic size.^{71,726,727} Specifically, intraoperative visualization of the posterior segment may become impaired when a silicone optic comes into contact with silicone oil or a gas bubble. A mild myopic shift has been recognized in some cases of combined surgery.^{728,729}

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 before the posterior segment procedure.

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 steepness. Keratorefractive steepening or flattening of the cornea therefore introduces a formula artifact. 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.⁷³⁰⁻⁷³³ 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 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.

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.^{734,735} 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.^{736,737}

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.^{653,738-741} Similarly, eyes that have had prior hyperopic photoablation are prone to myopic optical errors after cataract surgery.

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.⁷⁴²⁻⁷⁴⁷ It may be beneficial to utilize the Aramberri Double-K method to refine IOL power determination, because the surgically altered corneal curvature may render some calculation formulas less accurate.⁷⁴⁸ 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.

In order to bring together the most accurate IOL power calculation methodologies for patients who have previously undergone radial keratotomy, myopic or hyperopic photoablation, ASCRS has developed a regularly updated online IOL power calculator available at <http://iol.ascrs.org> or <http://one.aao.org/ce/iol.html>.^{244,749}

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 should be delayed until the refraction is stable.⁷³⁰

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.^{750,751} 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.⁷⁵² 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.⁷⁵³

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

Second-Eye Surgery

Clinical studies have provided convincing evidence that binocular summation occurs in individuals who have similar visual acuities in the two eyes and at low illuminance levels.⁷⁵⁴⁻⁷⁵⁹ In addition, these studies have demonstrated that binocular gain or summation is less likely when the visual acuities in the two eyes are dissimilar or when the individual is older. Indeed, these individuals with dissimilar acuities in the two eyes may exhibit binocular inhibition. Patients with a cataract and dissimilar vision in the two eyes (or one eye with cataract extraction and the second eye with a cataract) have demonstrated binocular inhibition.⁷⁵⁹ A large epidemiological study demonstrated that persons who exhibited binocular inhibition were more likely to have driving difficulties compared with those who did not have binocular inhibition.⁷⁵⁴ 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.^{173,760-765} Patients who had surgery in both eyes were significantly more satisfied with their visual function than patients who had surgery in only one eye.^{760,766} 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.⁷⁶⁷ 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.⁷⁶⁸ Cataract surgery for both eyes is an appropriate treatment for patients with bilateral cataract-induced visual impairment.^{760,762,763,769}

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.^{762,770}

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.^{771,772}

One study has suggested that a change in refraction from 1 week to 1 month postoperatively of 0.5 D or more occurs in only 1.2% of patients.⁷⁷¹

Sufficient time should elapse to diagnose and treat any early postoperative complication such as endophthalmitis, and for the patient and the ophthalmologist to be satisfied with the recovery and outcome of the first-eye surgery.

Immediate Sequential (Same Day) Bilateral Cataract Surgery

Most ophthalmologists do not perform immediate sequential bilateral cataract surgery on the same day. The rapid visual recovery and low complication rates associated with small-incision cataract surgery under topical anesthesia has led to increased interest in this approach in some international centers,⁷⁷³⁻⁷⁸⁶ particularly in health care delivery systems with long waiting times for cataract surgery in the second eye.^{773,783-785} 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 until the second surgery is performed.⁷⁸⁰⁻⁷⁸⁵ Assuming that it is the preference of a patient anticipating cataract surgery in both eyes, immediate sequential bilateral surgery has advantages and disadvantages that must be carefully weighed and discussed by the surgeon and patient. Foremost is the risk of potentially blinding complications in both eyes. For this reason the second eye should be treated like the eye of a different patient using separate povidone iodine prepping, draping, instrumentation, and supplies such as irrigating solutions, OVD, and medications. In published reviews, bilateral complications are rare,⁷⁷³⁻⁷⁷⁹ but there have been case reports of bilateral endophthalmitis occurring with simultaneous surgery when these guidelines for strict separation of the two surgical setups were not followed.^{781,782,787,788}

Another potential disadvantage of this approach is the inability to adjust surgical plans for the second eye on the basis of results from the first eye surgery.⁷⁷² 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 his or her experience with the first eye.⁷⁷²

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, rare occasions 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.^{774,777,786}

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.²³¹ 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 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 operating ophthalmologist is responsible for the care of the patient during the postoperative interval, the time in which most complications occur and within which stable visual function is achieved, as well as an ethical obligation to the patient that continues until postoperative rehabilitation is complete.

The operating ophthalmologist should also provide those aspects of postoperative eye care that are within the unique competence of the ophthalmologist. These do not necessarily include those aspects of postoperative care permitted by law to be performed by auxiliaries. If such follow-up care is not possible, the operating ophthalmologist must make arrangements before surgery to refer the patient to another ophthalmologist for postoperative care with the prior approval of the patient and the ophthalmologist.^{228,789,790} In rare special circumstances, such as emergencies or if no ophthalmologist is available, the operating ophthalmologist may make different arrangements for the provision of those aspects of postoperative eye care within the unique competence of the ophthalmologist, as long as the patient's rights and welfare are the primary considerations.

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. 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. Patients should always have access to an ophthalmologist for appropriate care if serious problems arise.

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.²²⁸

Postoperative regimens of topically applied antibiotics, corticosteroids, and NSAIDs vary among practitioners. 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 with topical ocular NSAIDs.⁷⁹¹⁻⁷⁹³

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.⁷⁹⁴⁻⁷⁹⁷

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.

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, and the patient should have ready access to the ophthalmologist's office to ask questions or seek care.

Components of each postoperative examination should include the following:

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

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 diagnose irregular corneal astigmatism. Automated visual fields may 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. 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 surgery⁷⁹⁸ and between 6 and 12 weeks after sutured large-incision cataract extraction surgery.

Posterior Capsular Opacification

Posterior capsular opacification often occurs following ECCE 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.³³⁹ The most common cause of PCO is proliferation of lens epithelial cells that remain in the capsular bag following cataract surgery.⁷⁹⁹

The time of onset of PCO from the time of surgery varies.^{800,801} The frequency with which Nd:YAG laser capsulotomy is performed also varies and has been reported in the range of 3% to 53% within 3 years' time.⁸⁰² The Cataract PORT study reported a 19.2% incidence of PCO occurring within 4 months of cataract surgery.⁴ 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 between 0 and 4.7%.^{803,804}

Younger patients often have more significant rates of PCO following cataract surgery than older patients. A longitudinal study in Sweden found that 10 years postoperatively 37% of patients under 65 at the time of surgery had been treated with Nd:YAG laser capsulotomy compared with 20% of the patients older than 65.⁸⁰⁵

A meta-analysis evaluated the efficacy of different IOL materials and optic edge designs in preventing PCO.³⁸⁵ Analysis of 23 randomized controlled trials found that sharp-edged hydrophobic acrylic IOLs and silicone IOLs were more effective in preventing PCO and Nd:YAG laser capsulotomy than PMMA IOLs and hydrophilic acrylic (hydrogel) IOLs. A Cochrane systematic review found no significant differences in PCO development between different IOL materials (PMMA, hydrogel, hydrophobic acrylic, and silicone). However, the hydrogel IOLs tended to have higher PCO scores and the silicone IOLs had lower PCO scores than the other IOL materials. This analysis did find that there was a significantly lower PCO score and Nd:YAG laser capsulotomy rate with sharp-edged versus round-edged IOLs.⁸⁰⁶

Substantial evidence supports a lower PCO rate when the anterior capsulorrhexis completely overlaps the entire optic.^{807,808} However, this may be a less important factor with single-piece foldable acrylic IOLs.⁸⁰⁹

Polishing of the anterior capsule has a variable effect on reducing PCO rates.^{810,811} However, anterior capsule fibrosis and contracture is more frequent with silicone than acrylic optic materials, and anterior capsule polishing may reduce this postoperative phenomenon.⁸¹⁰⁻⁸¹² No difference in PCO rates has been found with more prolonged administration of topical corticosteroids or topical NSAIDs.⁵⁶⁰⁻⁵⁶²

Nd:YAG laser capsulotomy is an effective surgical procedure to clear the visual pathway and restore visual function, and to improve contrast sensitivity.⁸¹³ 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. 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. These lenses reduce contrast sensitivity, which is further impaired by early PCO. Nd:YAG laser capsulotomy should not be performed prophylactically (i.e., when the capsule remains clear). Same-day bilateral Nd:YAG laser posterior capsulotomy may be appropriate when indicated.

Complications of Nd:YAG laser capsulotomy include increased IOP,⁸¹⁴ retinal detachment, damage to the IOL, and dislocation of the IOL.⁸¹⁵ Axial myopia increases the risk of retinal detachment after Nd:YAG laser capsulotomy,⁸¹⁶ as does pre-existing vitreoretinal disease, male gender, young age, vitreous prolapse into the anterior chamber, and spontaneous extension of the capsulotomy.⁸¹⁷ Two case series reported a 0% to 0.4% incidence of retinal

detachment 1 to 8 years following uncomplicated phacoemulsification and capsular fixation of the IOL.^{499,818} In one of these series, there were no retinal detachments in eyes with an axial length less than 24.0 mm.⁴⁹⁹ A case-control study found that, in the absence of a posterior capsule tear at the time of cataract surgery, subsequent Nd:YAG capsulotomy did not increase the risk of retinal detachment.⁸¹⁹

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.^{820,821} In the presence of risk factors, such as pre-existing glaucoma or inflammation, a variety of agents to lower IOP have demonstrated efficacy at blunting IOP elevation.⁸²²⁻⁸²⁷ Therefore, in high-risk patients, the surgeon should monitor the IOP in the early postoperative period.

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.⁸²⁸

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.^{227,228} Diagnosis and management require medical expertise, surgical skills, and specialized diagnostic and surgical equipment. The ophthalmologist's training, clinical experience, and judgment are necessary to evaluate the medical, ocular, and psychosocial factors used to determine the appropriateness and timing of surgery. Cataract surgery, including use of the femtosecond laser, should be performed only by an appropriately trained ophthalmologist.⁸²⁹

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

Nearly all cataract surgery is performed in an outpatient setting, which may be in a hospital-based outpatient department (HOPD) or freestanding ambulatory surgery center (ASC). The surgical facility should comply with local, state, and federal regulations and standards governing the particular setting of care. Inpatient surgery may be necessary if there is a need for complex anesthetic or surgical care, multiple procedures, or postoperative care requiring an acute-care setting.

COUNSELING AND REFERRAL

Patients with functionally limiting postoperative visual impairment should be referred for vision rehabilitation and social services.⁸³⁰ More information on vision rehabilitation, including materials for patients, is available at www.aao.org/smartsight.

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. 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, 2002.⁸³¹ 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.

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.⁸³² 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.⁸³² The rate of cataract surgery in the Veterans Health Administration (VHA) ranged

between 104.8 to 133.6 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.⁸³³

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.³⁴ 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 correlates to 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.³⁴ Cataract 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).^{834,835} 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 information that was recorded 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.⁸³⁶ 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.⁸³⁷ More recent studies have added a self-reported visual function questionnaire.⁸³⁸ 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.⁸³⁹ In 2009, 69% of cataract surgery with IOL insertion was performed in ASCs.⁸⁴⁰ Medicare payments to ASCs for all types of surgery totaled \$3.2 billion or \$102 per Medicare beneficiary in 2009.⁸⁴¹ Cataract surgery with IOL implantation was the most frequently performed surgical service in ASCs in 2009, accounting for 18% of the volume.⁸⁴² 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.⁸⁴³

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, medications, and new postoperative eyeglasses. 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.

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.⁸⁴⁴

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.

Estimates of the hypothetical cost per QALY gained for cataract surgery in one eye was estimated at US\$4500 in Sweden⁸⁴⁵ and US\$2023 in the United States.⁸⁴⁶ In a U.S. study done in 2003, the estimated cost per QALY gained for cataract surgery in the second eye was US\$2727.⁸⁴⁷ 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.

Medical technology is valuable if the benefits of medical advances exceed the costs. Cutler and McClellum analyzed technological advances in treatment of five conditions, including cataracts.²⁷ 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 other treatments: \$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.

Cost Considerations

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. 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.²⁹⁸ Costlier new infection control measures for ophthalmic surgery should not be arbitrarily imposed by regulatory agencies without evidence-based support.

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. There are two measures in the 2011 Physician Quality Reporting System program for cataract surgery. One measure is related to the visual outcome achieved and the other to major postoperative complications.⁸⁴⁸



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. NUTRITION AND CATARACTS

Most randomized controlled studies of nutritional supplements have not demonstrated a beneficial effect on cataract development or progression (Table A2-1). Observational studies of nutrition and cataract with more than 10,000 participants (Table A2-2) have reported either no association⁸⁴⁹ or a reduced risk.⁸⁵⁰⁻⁸⁵⁵

TABLE A2-1 SUMMARY OF RANDOMIZED CONTROLLED TRIALS OF NUTRITIONAL SUPPLEMENTS AND CATARACTS

Study	Date Published	Sample Size	Results
Beta Carotene			
Physicians' Health Study ¹³⁵	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 ¹³⁴	2004	39,876	No effect of treatment on cataract development
Multivitamin/Mineral			
Linxian Cataract ¹⁴⁴	1993	2,141	36% reduction in development of nuclear cataracts in a nutritionally deficient population
Nutritional Supplements and Age-Related Cataract ¹⁴³	2008	1,020	Nuclear sclerosis less common; PSC cataract more common
Riboflavin/Niacin			
Linxian Cataract ¹⁴⁴	1993	3,249	44% reduction in development of nuclear cataracts in a nutritionally deficient population
Vitamin C and E			
Physicians' Health Study II ¹⁴⁰	2010	11,545	No effect of treatment on cataract development
Vitamin C, E, and Beta Carotene			
Age-Related Eye Disease Study ¹³³	2001	4,629	No effect of treatment on the development or progression of cataracts
Antioxidants in Prevention of Cataracts Study ¹³⁶	2006	798	No effect of treatment on progression of cataracts
Roche European American Cataract Trial ¹⁴²	2002	297	No effect of treatment on the progression of cataracts in the United Kingdom group; small positive treatment effect in U.S. participants
Vitamin E			
Vitamin E, Cataract and Age-Related Maculopathy Trial ¹³⁷	2004	1,193	No effect of treatment on the development or progression of cataracts
Vitamin E and Beta Carotene			
Alpha-tocopherol, beta-carotene Cancer Prevention Study ¹³⁸	1997	1,828	No effect of treatment on the development or progression of cataracts

PSC = posterior subcapsular

TABLE A2-2 SUMMARY OF OBSERVATIONAL STUDIES OF NUTRITION AND CATARACTS (N >10,000)

Study	Date Published	Type of Study	Sample Size	Measure	Results
Dietary Intake					
European Prospective Investigation into Cancer and Nutrition ⁸⁵⁴	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
Fat Intake					
Nurses' Health Study ⁸⁵³	2005	Prospective cohort	71,083	Dietary intake	Reduced risk of cataract extraction with higher intake of long-chain fatty acid and consumption of fish
Fruit and Vegetable Intake					
Women's Health Study ⁸⁵⁰	2005	Prospective cohort	35,724	Dietary intake	Reduced risk of cataracts associated with higher intakes of fruits and vegetables
Multivitamin Supplement					
Nurses Health Study ⁸⁴⁹	1992	Prospective cohort	50,828	Supplement use	No association for multivitamin use and cataract extraction
Physicians Health Study ⁸⁵¹	1994	Prospective cohort	17,744	Supplement use	Reduced risk of cataracts
Riboflavin/Niacin					
Nurses Health Study ⁸⁴⁹	1992	Prospective cohort	50,828	Total dietary intake	No association
Vitamin C					
Japan Public Health Center-based Prospective Study ⁸⁵⁵	2007	Prospective cohort	35,186	Total dietary intake	Reduced incidence of cataract diagnosis or extraction with higher vitamin C intake
Nurses Health Study ⁸⁵²	1992	Prospective cohort	50,828	Supplement use	Reduced risk of cataract extraction with 10 years' or less use
Vitamin E					
Nurses' Health Study ⁸⁴⁹	1992	Prospective cohort	50,828	Total dietary intake and supplement	No association



APPENDIX 3. 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.



**AMERICAN ACADEMY
OF OPHTHALMOLOGY**
The Eye M.D. Association

This checklist may be downloaded from <http://one.aao.org/CE/PracticeGuidelines/Patient.aspx>. Choose the Recommendations of American Academy of Ophthalmology Wrong-Site Task Force Patient Safety Bulletin (November 2008) and click on Full Text.



LIST OF ABBREVIATIONS

ADVS: Activities of Daily Vision Scale
AMD: age-related macular degeneration
ASC: ambulatory surgery center
ASCRS: American Society of Cataract and Refractive Surgery
BCVA: best-corrected visual acuity
CME: cystoid macular edema
D: diopter
ECCE: extracapsular cataract extraction
ESCRS: European Society of Cataract and Refractive Surgeons
EVS: Endophthalmitis Vitrectomy Study
HEMA: hydroxy ethyl methacrylate
HOPD: hospital-based outpatient department
IFIS: intraoperative floppy iris syndrome
IOL: intraocular lens
IOP: intraocular pressure
Nd:YAG: neodymium: yttrium-aluminum-garnet laser
NEI-VFQ: National Eye Institute-Visual Function Questionnaire
NEON: National Eyecare Outcomes Network
NSAID: nonsteroidal anti-inflammatory drug
OVD: ophthalmic viscosurgical device
PCO: posterior capsular opacification
PMMA: polymethyl methacrylate
PORT: Patient Outcomes Research Team
PPP: Preferred Practice Pattern
PSC: posterior subcapsular
TASS: toxic anterior segment syndrome
QALY: quality-adjusted life year
VF-14: Visual Function Index
VHA: Veterans Health Administration



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Cataract (Spanish: Catarata) (2011)

Cataract Surgery (2011)

Eye Care Facts & Myths (2010)

Seeing Well as You Grow Older (2011)

Patient Education DVD

Understanding Cataract Surgery (2009) (includes English and Spanish)

Understanding IOL Options for Cataract Surgery (2009) (includes English and Spanish)

Patient Safety Bulletin

Recommendations of American Academy of Ophthalmology Wrong-Site Task Force (2008) – Available at: <http://one.aao.org/CE/PracticeGuidelines/Patient.aspx>

Performance Improvement CME

Wrong Site/Wrong IOL Performance Improvement CME – Available at:

<http://one.aao.org/ce/educationalcontent/performanceimprovementcme.aspx>

Preferred Practice Pattern

Comprehensive Adult Medical Eye Evaluation (2010) – Available at: www.aao.org/ppp

To order any of these materials, please call the Academy's Customer Service number, 866.561.8558 (U.S. only) or 415.561.8540 or visit www.aao.org/store.



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