# Canadian Ophthalmological Society evidence-based clinical practice guidelines for cataract surgery in the adult eye

Canadian Ophthalmological Society Cataract Surgery Clinical Practice Guideline Expert Committee

## Introduction

The development of these guidelines was initiated by the Canadian Ophthalmological Society (COS) Board of Directors, who felt that the time was appropriate for Canadian clinical practice guidelines on the provision of eye care and cataract surgery within the Canadian health care context and based on the best evidence in the literature and expert opinion. Subsequently, the Canadian Medical Association (CMA) encouraged all medical specialty organizations to develop Canadian clinical practice guidelines that could be used to help justify patterns of practice, as efforts were being undertaken to shorten wait times for a variety of procedures, including cataract surgery.

The objective of this document is to provide guidance to Canadian surgical ophthalmologists and allied health care professionals on current indications for surgery and pre-, peri-, and postoperative considerations for adult cataracts to minimize risk and maximize successful patient outcomes.

These guidelines were developed using the best available evidence and are intended to inform patterns of clinical practice. These guidelines are not meant or intended to restrict innovation, nor are they intended to provide a "cookbook" approach to medicine or be a replacement for clinical judgment.[1] Furthermore, these guidelines should not be used as a legal resource, as their general nature cannot provide individualized guidance for all patients in all circumstances.[1] There is no expectation that these guidelines be applied in a research setting. These guidelines do not attempt to comment on the financial impact of procedures recommended.

Ideally, guidelines are flexible tools that are based on the best available scientific evidence and clinical information, reflect the consensus of professionals in the field, and allow physicians to use their individual judgment in managing their patients.[2] Indeed, ophthalmologists must consider the needs, preferences, values, and financial and personal circumstances of individual patients and work within the realities of their health care setting. It is understood that there are inequities in human, financial, and health care resources in different regions of the country and that these factors may effect physician and patient options and decisions.

These guidelines will be periodically reviewed by the COS Clinical Practice Guideline Steering Committee, and will be updated as necessary in the light of new evidence.

## Cataract—a public health issue

A cataract is a clouding of the lens in the eye that interferes with vision. Surgery to remove the cataract and replace it with an artificial lens is usually undertaken when the clouding interferes with a patient's activities of daily living. Cataract is a major public health issue, especially in developing countries, since it is responsible for 47.8% of total blindness in the world.[3] In 2003, Canadian provincial governments paid $121 459 657 to physicians for cataract surgery (this does not include facility costs), which amounted to 0.098% of total health care expenditures during that year.[4] Cataract surgery is cost-effective for the first eye[5] and even more so for the second eye,[6,7] even in patients with low probability of vision improvement (<30%).[8] The cost per quality-of-life years gained ranges from $2023 to $2727 in the United States for cataract surgery depending on whether the first or second eye is considered.[9] This compares very favourably with the range of procedures funded by a public system (e.g., hip arthroplasty $2279, knee arthroplasty $6535, implantable defibrillator $21 804).[10]

In 2002, over one-quarter of a million patients had cataract surgery in Canada, a 32% increase over 1997.[11] This resulted in a rate of approximately 8000 cases per million persons in Canada, midway between the reported rates in the United States (7000/million) and Australia (9000/million).[12] Although some of this increase was due to Canada's aging population, much was related to changing thresholds for surgery[13] brought on by improvements

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in surgical outcomes.[14] The demand for cataract surgery is anticipated to soar over the next 25 years. Because of the projected demographic shifts in the country, cataract prevalence is expected to rise from 1/343 500 people in 2006 to 1/20 600 in 2031—a 90% increase.[15] Improved surgical technology and safety could push this demand even higher.

## Methods

An English-language literature search for the years 2002 to 2007 was conducted using PubMed, EMBASE, the Cochrane Library, the National Guideline Clearing House, and the United States Preventative Services Task Force databases. Furthermore, a hand search of the reference lists and tables of contents of the most recent issues of major ophthalmology and cataract journals was performed to locate seminal papers published before 2002 and to take into account the possible delay in the indexing of the published papers in the databases. Citations such as press news, nonhuman studies, congenital studies, child studies, in vivo studies, molecular genetics studies, and meeting abstracts were removed. Selected references were independently reviewed by at least 2 committee members to ensure they were relevant and of acceptable methodological quality.

References used to support recommendations were assigned a level of evidence based upon the criteria specified in other national published guidelines[16,17] and outlined in Table 1. Recommendations were formulated using the best available evidence. Health benefits, risks, and side effects of interventions were considered in formulating the recommendations. In the absence of direct evidence, recommendations were written to reflect unanimous consensus of the Expert Committee. In the event of disagreement, wording changes were proposed until all committee members were in agreement. The citations used by the committee to arrive at consensus are indicated in the relevant preamble preceding each recommendation.

Where possible, the content of this document was developed in accordance with the Canadian Medical Association *Handbook on Clinical Practice Guidelines*[1] and the criteria specified in the 6 domains of the *Appraisal of Guidelines Research and Evaluation (AGREE) Instrument.*[18] These domains cover the following dimensions of guidelines: scope and purpose, stakeholder involvement, rigour of development, clarity and presentation, applicability, and editorial independence. A draft version of the document was reviewed by numerous experts (ophthalmologists, optometrists, family physicians, and anesthesiologists) from across Canada and from a variety of practice settings. Revisions were incorporated where relevant.

## Risk management

The issues of risk management in cataract surgery are similar to those in many other areas of medicine. A collaborative retrospective analysis of legal actions pertaining to cataract surgery in the United Kingdom over the 10-year period from January 1990 to December 1999 showed that the majority concerned well-recognized complications of cataract surgery.[19] The study showed that even a relatively good visual outcome does not protect against potential litigation. Factors felt to increase the risk of successful litigation are inadequate informed consent, poor communication between patient and surgeon both before and after the surgery, and inadequate pre-, intra-, and postoperative documentation. One example of an informed consent specifically designed for cataract surgery was produced by the Royal College of Ophthalmologists in the U.K.[20] Implementation of a systems approach that focuses on patient safety outcomes by identifying clinical incidents and analyzing both expected and unexpected surgical complications is advocated.[21,22]

### Recommendations

1. In order to optimize patient outcomes and reduce risk in cataract surgery, strict attention should be paid to the principles of informed consent, excellent communication and meticulous documentation, in a setting of continuous quality improvement [*Consensus*].

To maintain competency for any surgical procedure surgeons must perform a minimum number of procedures per year. There is insufficient evidence to define this threshold in cataract surgery.[23] There are good epidemiologic data demonstrating that the rate of posterior segment complications from cataract surgery drops as surgeon volume increases. This is true, in this study, at all levels of surgical volume. It is worth noting that the complication rate for all surgeons involved in this study (regardless of volume) was within acceptable rates as defined in the literature.[23]

Lastly, strict attention to detail, risk assessment, and careful consideration of the patient pathway is needed to enhance cataract care. Clinical errors, near misses, and complications occur, and these may provide an opportunity for learning to reduce the risk of similar events in the future. Investment in staffing, training, appropriate equipment, and development of a safety culture with patient involvement are key elements of safe cataract surgical care.[21]

## Options prior to cataract surgery

The main nonsurgical option to cataract surgery is to change the patient's refractive correction. If there is a large discrepancy between the patient's presenting visual acuity and best-corrected visual acuity, optical correction should be considered before surgery. Other nonsurgical options to cataract surgery include the use of tinted lenses, pupillary dilation for small central cataracts, and magnifiers for reading, but such options have only a limited role. Patients

with cataracts that are subthreshold for surgery should be informed about the epidemiologic link between cataract development and smoking, steroid use, diabetes, and ultraviolet ray exposure. Such patients may benefit from lifestyle modification. Nutritional supplementation has not been shown to reduce the rate of cataract development.[24]

### Indications for cataract surgery

Cataract surgery is appropriate when performed on patients who have difficulties with their activities of daily living that are caused by their lens opacity. These problems often involve, but are not limited to, seeing fine details (reading, driving, watching television), problems with visual aberrations (glares, haloes), and problems with binocularity (anisometropia, aniseikonia, colour abnormalities). Surgery is also appropriate when these difficulties are situational, such as when they only occur at night. Cataract surgery has been shown to reduce the risk of falls by 34% over 1 year and to reduce the annual fracture rate from 8% to 3% in women >75 years with clinically significant cataracts.[25] Cataract surgery in at least 1 eye has also been shown to reduce the rate of motor vehicle accidents by 53% compared with patients with cataracts who declined surgery.[26] Cataract surgery has also been shown to reduce frequent nocturnal wakenings and daytime sleepiness over a few months after surgery in elderly persons.[27,28]

There also exist legal visual acuity standards for certain activities (e.g., driving, military service). In circumstances where a patient's visual acuity falls below legal limits, it is entirely appropriate, and in some jurisdictions it is mandatory, to inform the patient and the relevant authorities of the visual impediment. In these cases, cataract surgery is indicated if the patient wishes to continue the activity in question, even in the absence of self-reported visual difficulties.

Sometimes cataract surgery is indicated to allow better management of posterior segment disease or to treat phacomorphic glaucoma or phacoanaphylactic uveitis. Patients with medical indications for surgery need to be made aware that the primary reason for surgery is to improve or maintain the health of their eye. Although visual improvement generally occurs, they should be informed that this is not the primary reason for surgery.

Due to the slow, progressive decline in vision associated with the development of cataracts, many patients are not aware of the decrease in visual function brought on by their cataracts. If the surgeon suspects significant impairment of which the patient seems unaware, collateral information from friends, relatives, and the family physician is useful in identifying patients who would appropriately benefit from surgery but are incapable of personally identifying a visual deficit. If these patients cannot be convinced of the need for surgery, the increased risk of falls, fractures, and motor vehicle accidents should be explained to them.

Patients who have a clearly identified functional deficit before surgery tend to have higher appropriateness scores and have superior postsurgical outcomes in terms of both visual improvement and self-reported visual function.[29,30]

Cataract surgery is contraindicated if spectacle or other visual aids provide vision that meets the patient's needs, surgery will not improve visual function, the patient cannot safely undergo surgery, or appropriate postoperative care is not available.[24]

**Table 1—Criteria for assigning levels of evidence to the published studies**

| Level | Criteria |
|---|---|
| Studies of diagnosis | |
| Level 1 | (*i*) Independent interpretation of test results (without knowledge of the result of the diagnostic or gold standard) |
| | (*ii*) Independent interpretation of the diagnostic standard (without knowledge of the test result) |
| | (*iii*) Selection of people suspected (but not known) to have the disorder |
| | (*iv*) Reproducible description of both the test and diagnostic standard |
| | (*v*) At least 50 patients with and 50 patients without the disorder |
| Level 2 | Meets 4 of the Level 1 criteria |
| Level 3 | Meets 3 of the Level 1 criteria |
| Level 4 | Meets 1 or 2 of the Level 1 criteria |
| Studies of treatment and prevention | |
| Level 1A | Systematic overview or meta-analysis of high-quality, randomized, controlled trials |
| | Appropriately designed randomized, controlled trial with adequate power to answer the question posed by the investigators |
| Level 1B | Nonrandomized clinical trial or cohort study with indisputable results |
| Level 2 | Randomized, controlled trial or systematic overview that does not meet Level 1 criteria |
| Level 3 | Nonrandomized clinical trial or cohort study |
| Level 4 | Other |
| Studies of prognosis | |
| Level 1 | (a) Inception cohort of patients with the condition of interest, but free of the outcome of interest |
| | (b) Reproducible inclusion/exclusion criteria |
| | (c) Follow-up of at least 80% of subjects |
| | (d) Statistical adjustment for extraneous prognostic factors (confounders) |
| | (e) Reproducible description of outcome measures |
| Level 2 | Meets criterion (a) above, plus 3 of the other criteria |
| Level 3 | Meets criterion (a) above, plus 2 of the other criteria |
| Level 4 | Meets criterion (a) above, plus 1 of the other criteria |

### Recommendations

2. Cataract surgery is indicated primarily for the correction of visual impairment that cannot be adequately improved nonsurgically and that is directly attributable to the presence of a lens opacity [*Level 3*[31]].
3. Even in the absence of functional symptoms, cataract surgery is indicated to meet visual acuity standards when a patient's visual acuity falls below legal standards for activities (such as driving, military service, or flying) and the patient wishes to continue to perform these activities [*Consensus*].

4. Patients who decline surgery, even after consultation with collateral sources of information, should be made aware that cataract surgery, where indicated, has been shown to decrease the incidence of motor vehicle accidents [*Level 2*[26]] and in patients at high risk, to decrease falls and fractures [*Level 2*[25]].
5. Cataract surgery is indicated for medical reasons, such as phacomorphic glaucoma, lens-induced uveitis, or treatable posterior segment pathology, that cannot be adequately managed due to lens opacity [*Consensus*].

### Prioritization

Recent attention has been paid to the effects of wait time for cataract surgery on patient outcomes. A qualitative synthesis of studies related to wait time for phacoemulsification surgery showed that patients who wait >6 months for cataract surgery may experience negative outcomes during the wait period, including vision loss, a reduced quality of life, and an increased rate of falls.[32] Although waiting time actually starts when a patient seeks primary care for a visual problem, there are no studies in the literature addressing the effects of this wait on patients.

The accumulated morbidity after waiting 1 year for cataract surgery is significant. Patients who are at immediate risk of losing their driver's licence or losing their ability to carry out societal roles (e.g., work, care-giving, activities of daily living) should be prioritized if their surgery cannot be carried out in a timely manner.[33] It appears that the accumulation of morbidity is linear over time, at least with regards to injuries.[34] A prospective cohort study demonstrated that patient satisfaction with actual wait time decreased significantly as the waiting time increased.[35] The Canadian Wait Time Alliance has set the Canadian benchmark for cataract surgery within 4 months of specialist consultation.[36]

#### Recommendations

6. Cataract surgery should be performed within 4 [*Consensus*] to 6 [*Level 3*[32,37]] months of specialist consultation to minimize the risks of falls, fractures, and motor vehicle accidents. In jurisdictions where this cannot be accomplished, in addition to attempting to shorten wait times by procuring more resources, consideration should be given to a prioritization scheme to allow patients who are more at risk to be triaged [*Consensus*].

### Ophthalmic workup

A complete ocular history and physical will generally identify whether a patient has an alternate cause for vision loss other than cataract. Components of an ophthalmic evaluation relevant for the diagnosis and treatment of cataract are shown in Table 2. There is no questionnaire, scale, or history question that has been shown to be superior or optimal for assessment of visual impairment. When assessing indications for surgery, the circumstance that causes the most difficulty is the presence of mild to moderate macular pathology (most commonly age-related macular degeneration [AMD]) in combination with a mild to moderate cataract. In this circumstance, a variety of anatomic tests (e.g., optical coherence tomography [OCT]) and macular function tests (e.g., potential acuity meter, laser interferometry) may be helpful;[38] however, clinical judgment ultimately dictates whether surgery is appropriate. Although surgical success rates are lower in the very elderly, cataract surgery can be carried out even in very elderly patients (>95 years) with reasonably low complication rates.[39]

**Table 2—Ophthalmic evaluation for the diagnosis and treatment of cataract[24]**

| Evaluation | Details |
|---|---|
| Patient history | Patient's assessment of functional status |
| | Pertinent medical conditions |
| | Current medications |
| | Allergies to medications and (or) latex |
| | Risk factors that could affect the surgical plan |
| | Previous ophthalmic surgery, including refractive surgery |
| Measurements | Visual acuity with current correction at distance and (when appropriate) at near |
| | Best-corrected visual acuity, including under glare conditions |
| | Intraocular pressure |
| Examinations | External (lids, lashes, lacrimal apparatus, orbit) |
| | Ocular alignment and motility |
| | Slit-lamp biomicroscopy of the anterior segment |
| | Dilated examination of the lens, macula, peripheral retina, optic nerve, and vitreous; B-scan ultrasound of fundus if inadequate view clinically |
| | Assessment of relevant aspects of the patient's mental and physical status |

Underlying ocular disease that can be exacerbated by cataract surgery includes Fuchs endothelial dystrophy, glaucoma, diabetic retinopathy, uveitis, and AMD. These will be discussed separately below.

Ocular conditions that may complicate cataract surgery include the above conditions as well as pseudoexfoliation syndrome, retinopathy of prematurity, corneal clouding, a deeply set eye, extremes of axial length, a miotic pupil, prior corneal, glaucoma or retinal surgery, posterior synechiae, a posterior polar cataract, zonular laxity, and a brunescent or mature (white) cataract. Systemic conditions that may complicate surgery include head tremors, problems with lying flat for surgery, use of alpha1-adrenergic blocking agents (which can lead to intraoperative floppy iris syndrome [IFIS]) or autoimmune disease (which can lead to surgical-induced necrosis syndrome).[24]

#### Recommendations

7. The ophthalmic work-up of a patient being considered for cataract surgery should answer the following questions:
   a) Is the cataract primarily responsible for the vision loss?

b) Are there any comorbid conditions that may be exacerbated by the surgery?
c) Are there any comorbid conditions that may complicate the execution of the surgery or minimize the visual improvement?
Answering these questions allows the stratification of surgical risk that should be presented to the patient as part of the consent process [*Level 3*[40]].

8. As surgical cases of increased difficulty can sometimes be predicted preoperatively and are also associated with an increased risk of complications [*Level 3*[41]], surgeons must realistically evaluate the anticipated difficulty of high-risk cases and refer if the anticipated difficulty exceeds their personal level of competence [*Consensus*].

### *Outcome measures*

Outcome measures should be varied and should match the indications for surgery.[30,42] Hence, surgery carried out for visual functional impairment should be assessed using a visual function tool or scale; surgery carried out for diminished visual acuity causing loss of driving privileges should be assessed based on improvement of visual acuity allowing a resumption of driving; and surgery carried out for other ocular disease should be assessed based on the resolution of, or the enhanced ability to treat, the underlying condition.

A prospective study from Australia analyzed patients' preoperative expectations for postoperative outcomes and concluded that the improvement in visual function experienced by a patient did not significantly correlate with overall satisfaction. The authors suggest that "controlling patient expectations may be more effective than improving patients' postoperative outcome in terms of maximizing patient satisfaction."[43]

#### RECOMMENDATIONS

9. In order to be valid, outcome measures should be varied and should match the indications for surgery [*Level 4*[30,42]].

## SPECIAL CIRCUMSTANCES

### *Monocular patients*

Functionally monocular patients have the same indications for surgery as other patients. The cause of vision loss in the contralateral eye is important in planning cataract surgery especially if vision loss in the fellow eye was the result of surgical complications.

#### RECOMMENDATIONS

10. Surgery in monocular patients should be carried out when the benefits outweigh the risks and should not be delayed solely due to monocular status, as this may increase the surgical risk due to increasing maturity of the cataract [*Level 3*[44–46]].

### *Second-eye cataract surgery*

The benefits of having cataract surgery done on the second eye have been clearly demonstrated in terms of improvement in functional status, stereopsis, binocular visual function, and binocular contrast sensitivity.[47,48]

#### RECOMMENDATIONS

11. The indications for second-eye surgery are the same as for the first eye, but the threshold for intervention is typically lower, particularly in patients with anisometropia. The interval between surgeries should be sufficient to diagnose and treat early postoperative complications (such as endophthalmitis) and determine the postoperative refractive error in the first eye [*Consensus*].

### *Simultaneous bilateral cataract surgery*

Traditionally, cataract surgery is performed one eye at a time. After a successful monocular operation, there can be a delay of weeks to months before the second surgery. In quality-of-life studies, patients report partial gains after 1 eye has had surgery and report complete satisfaction only after both eyes have been rehabilitated.[49] Rapid visual rehabilitation is desirable, especially for those who work or wish to retain independence (e.g., driving). In recent years, bilateral simultaneous cataract surgery (also known as immediately sequential[50] or same-day cataract surgery) has become more commonly performed in a limited number of jurisdictions around the world.[49–51] In addition to reducing systemic risks of going to the operating room (i.e., perioperative and [or] intraoperative systemic events), being more convenient for the patient, and offering more rapid visual rehabilitation, there are resource efficiencies associated with same-day surgery.[50,51] However, patients who undergo bilateral surgery face the risk of bilateral complications[51] (including endophthalmitis, toxic anterior segment syndrome [TASS], corneal edema, and retinal complications) that, in a worst-case scenario, can lead to loss of vision in both eyes. Patients must therefore be fully informed about the pros and cons of bilateral surgery, and patient uncertainty should be an absolute contraindication.[51] Unfortunately, reports on the routine performance of this procedure in the peer-reviewed literature are currently limited, and the paucity of safety data preclude recommending routine simultaneous bilateral cataract surgery at this time.

#### RECOMMENDATIONS

12. Due to the possibility of bilateral endophthalmitis [*Level 4*[52,53]] and bilateral TASS [*Consensus*], routine performance of simultaneous bilateral cataract surgery is not currently recommended [*Consensus*].
13. In patients for whom the benefits outweigh the risks in the opinion of the surgeon and patient, simultaneous bilateral cataract surgery may be considered.

Examples of such patients would include those with bilateral visually significant cataracts for whom there are significant problems with carrying out staggered unilateral surgery (such as significant perioperative medical risks, a requirement for general anesthesia, or significant travel problems) [*Consensus*]. Appropriate discussion of the pros and cons of simultaneous bilateral cataract surgery versus one eye at a time should be individualized. The patient must be informed of the comparative risks [*Consensus*].

14. If simultaneous bilateral cataract surgery is scheduled, the 2 eyes should be performed as 2 separate procedures (re-prep, re-gown, new instruments, different lot numbers for all drugs, solutions, and instrumentation when possible) [*Level 3*[50]] and care should be taken after the first procedure to ensure that no significant complication (such as posterior capsule rupture) has occurred [*Level 3*[50]]. In the case of significant complications with the first eye, surgery on the second eye should be deferred [*Level 3*[50]].

### *Cataract in the presence of age-related macular degeneration*

There are 3 large studies that prospectively examined the progression of AMD after cataract surgery. Two of these found an association[54,55] and one did not.[56] There is also evidence suggesting inflammation may worsen AMD.[57] Thus, careful pre- and postoperative screening of patients with AMD for treatable macular lesions should be performed. However, cataract surgery still results in excellent visual outcomes in appropriately selected patients with AMD, with 82% reaching 20/40 or better vision after surgery.[58]

#### RECOMMENDATIONS

15. Patients with both cataract and AMD should have surgery carried out if they have significant visual symptoms and a reasonable likelihood of visual improvement [*Level 1B*[54]]. They should be made aware that their AMD may limit their final visual outcome [*Level 1B*[54]] and be made aware of the possibility of worsening of their AMD with cataract surgery.

### *Cataract in the presence of corneal disease*

Corneal epithelial and stromal disease complicates cataract surgery by impairing visibility. Corneal endothelial disease is exacerbated by the expected loss (8%–13%) of endothelial cells associated with cataract surgery.[59]

Patients with Fuchs endothelial dystrophy should have cataract surgery alone performed when there is a reasonable expectation that corneal decompensation will not occur as a result of surgery. This is a clinical judgment aided by history (morning visual blur), physical exam (corneal edema), and tests (pachymetry[59] and endothelial cell count). The risks of permanent corneal edema due to corneal decompensation should be discussed.

#### RECOMMENDATIONS

16. If the cataract is the primary cause of vision loss and visibility is adequate for surgery, then cataract surgery alone is indicated [*Consensus*].
17. Patients with Fuchs endothelial dystrophy and cataracts should be considered for combined cataract and corneal surgery when, in the surgeon's judgment, the risk of corneal decompensation from cataract surgery alone is high enough to make visual improvement unlikely [*Consensus*].

### *Cataract in the presence of glaucoma*

The management of glaucoma in the presence of cataracts is beyond the scope of these guidelines and will be discussed in the upcoming COS guidelines on glaucoma. However, there are considerations that need to be made when planning cataract surgery in the patient with glaucoma. Potentially, there are 3 ways to manage patients with both conditions:[60] (*i*) perform cataract surgery and medically manage the glaucoma, (*ii*) perform glaucoma filtration surgery and then cataract surgery when necessary, or (*iii*) combine cataract and glaucoma surgery. Glaucoma surgery can cause progression of cataracts.[61] In one cohort of 69 eyes with previous glaucoma filtering surgery undergoing cataract surgery, only 2 patients developed bleb failure requiring reoperation.[62] Thus, patients with visually significant cataracts and previous filtering surgery can have cataract surgery performed with low risk of postoperative bleb failure.[62] Cataract surgery can cause intraocular pressure (IOP) spikes that can damage the optic nerve.[63] Patients who are on ≥3 glaucoma medications, who have intraoperative pupillary manipulation, or who have vitreous loss are significantly more likely to have an IOP spike (>10 mm Hg increase from baseline) after cataract surgery.[63]

#### RECOMMENDATIONS

18. In patients with glaucoma undergoing cataract surgery, if they are at high risk for a postoperative IOP spike and are at risk of losing fixation from their glaucoma, consideration should be given to combined cataract and glaucoma surgery [*Consensus*].
19. In patients with visually significant cataracts and medically uncontrolled glaucoma, consideration should also be given to combined surgery [*Consensus*].

### *Cataract in the presence of diabetes*

Cataract surgery can cause progression of underlying diabetic retinopathy, including diabetic macular edema. Care should be taken to adequately document the preoperative status of the retina.[64–66]

**RECOMMENDATIONS**

20. When possible, all clinically significant macular edema or proliferative diabetic retinopathy should be treated prior to cataract surgery [*Consensus*]. More serious retinal pathology like tractional detachments may benefit from combined cataract and vitrectomy surgery [*Level 3*[64]].
21. Patients should be advised that cataract surgery can cause progression of their diabetic retinopathy [*Level 4*[67,68]].

### *Cataract in the presence of chronic intraocular inflammation*

There are numerous diseases and syndromes associated with intraocular inflammation. The results of cataract surgery depend strongly on the type of uveitis (anterior/posterior, acute/chronic), as well as the specific disease entity. In the presence of chronic uveitis, surgeons should be aware of the increased risks associated with surgery and patients need to be aware of the poorer visual outcomes of surgery in this setting, particularly with disease entities associated with macular or optic nerve damage.[69,70]

**RECOMMENDATIONS**

22. Cataract surgery done for visual rehabilitation in eyes with chronic uveitis should be performed only after best possible control of active inflammation has been achieved for 3 months preoperatively, unless the risk of delaying surgery outweighs the benefits [*Consensus*].

### *Cataract in the presence of pseudoexfoliation syndrome*

Pseudoexfoliation syndrome, due to its effect on the pupil size and zonular apparatus, increases the risk of posterior capsule rupture, zonular disruption, and dropped nucleus.[71,72] Anterior chamber depth (ACD)—either excessively shallow or deep—can be an indirect sign of zonular weakness, and in pseudoexfoliation syndrome, a preoperative ACD of <2.5 mm was found to result in a nearly 5-fold increased risk of complications in one study.[73] The use of a capsular tension ring (CTR) is beneficial in reducing intraoperative complications and improving postoperative intraocular lens (IOL) centration in pseudoexfoliation syndrome.[74]

**RECOMMENDATIONS**

23. ACD should be assessed in cases of pseudoexfoliation syndrome. An ACD in pseudoexfoliation syndrome of <2.5 mm should raise concern of potential zonular weakness and increased risk for surgical complications [*Level 3*[73]].

### *Cataract combined with or after vitrectomy surgery*

While technically more challenging, cataract surgery after vitrectomy surgery has similar outcomes to standard cataract surgery, with visual outcomes being determined by the retinal status.[75,76] Combined cataract and vitrectomy surgery is used in cases of cataract in combination with posterior segment pathology, such as proliferative diabetic retinopathy, macular holes, and epiretinal membranes.[77] There are no studies in adults comparing pars plana lensectomy to phacomemulsification in combination with vitrectomy; however, phacoemulsification may be preferable in combined surgery because it allows in-the-bag lens placement.[77]

## PERIOPERATIVE CARE OF THE PATIENT UNDERGOING CATARACT SURGERY

The goals of perioperative care are to identify and manage actual and potential medical comorbidities that may adversely impact health or surgical success and to provide pain-free surgery by the most ideal mode of anesthetic administration with a minimum of anxiety, nausea, and vomiting.

### *Identification and management of medical comorbidities*

Self-administered health care questionnaires have been proposed as a replacement for routine history and physical examination by a health care provider. When they have been compared with gold standard history and physical examinations by a health care provider, they are >90% specific but <60% sensitive for renal disease, chronic obstructive pulmonary disorder (COPD) and (or) asthma, bleeding disorder, liver disease, anemia, and congestive heart failure.[78] In this study, the 35.3% of patients who reported no comorbidities had an overall 40% lower rate of intraoperative medical events compared with all study patients. This suggests that, with refinements, these types of questionnaires could identify the subset of patients in need of health care provider history and physical.

A randomized clinical trial of 19 250 cataract surgeries showed no value to routine preoperative medical testing before cataract surgery.[79] In the trial, there were 375 (1.95%) adverse medical events, with 66 (0.34%) patients who were hospitalized or died intraoperatively or up to 1 week postoperatively (8 admissions, no deaths the day of surgery).[79] This study did not exclude patients with preexisting medical problems and found no benefit irrespective of the type of setting of the cataract centre, age, sex, coexisting illness, American Society of Anesthesiologists risk class, self-reported health status, or race of the patient.

The recognition of several pre-existing conditions can, however, alter the treatment plan if discovered before surgery:

- **Allergy to natural rubber latex.** Preoperative skin testing and latex antibodies are of questionable value in predicting a serious responder.[80,81] The patient should be booked as the first case of the day to reduce exposure to airborne particles, and latex-free products should be used.
- **Allergy to iodine or intravenous pyelography (IVP) dye.** Iodine is an essential element to human

physiology. "Little evidence exists that elemental iodine is responsible for idiosyncratic contrast reactions or povidone-iodine dermatitis and no evidence exists that it is involved in seafood allergy. The notion that iodine confers specific cross-reactivity between these agents is unfounded."[82] In patients with povidone-iodine dermatitis, an alternative skin preparation solution with a nonalcohol, aqueous-based chlorhexidine skin preparation and conjunctival antibiotic prophylaxis should be considered. In patients with iodine, IVP dye, or seafood allergies, the evidence supports the use of povidone-iodine for skin preparation. The use of sterile 5% povidone-iodine in the conjunctival sac is also supported for patients reporting these allergies. There is no reported safety profile for its use in the conjunctival sac in the presence of skin allergy to povidone-iodine.

- **Methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE) patients.** Book patient last in the day[83] and sequester pre- and postoperatively.[84]
- **Ventricular defibrillating devices.** Bipolar and monopolar electrocautery can trigger a discharge of the device[85] and should be avoided. However, there are no reported cases of an adverse medical event during cataract surgery. Decommissioning the device may lead to ventricular tachycardia or fibrillation and should be considered with caution. Defibrillation during surgery can cause sudden head movements.
- **Fasting.** For all types of anesthesia, the Canadian Anesthesiologists' Society guidelines[86] recommend a 2-hour fast after clear fluid intake and a 6-hour fast after a light meal of clear fluids and toast. A U.K. survey of 50 hospitals (100% response rate) revealed that of the 86% of hospitals with a formal fasting policy, 44% allowed eye patients undergoing regional anesthesia to eat and drink freely until their operation.[87] Anesthesia guidelines are aimed at eliminating the risk of aspiration, which is only present when drugs that interfere with an individual's basic protective reflexes have been administered. If topical anesthesia without intravenous (IV) opiate or sedative is administered, fasting is not necessary. At the present time there is no uniform policy in Canada with regard to fasting for cataract surgery involving IV sedation or infiltration anesthesia. Patients with diabetes who are fasting and on insulin or oral antihyperglycemic agents require special medical management to avoid hypoglycemia. Scheduling a patient with diabetes early in the day shortens the fasting period.
- **Anticoagulants and platelet inhibitors.** In a study of 19 283 cataract surgeries, 13.8% of the 4588 aspirin users and 10.5% of the 752 warfarin users were advised to stop their aspirin or warfarin before surgery.[88] The authors concluded that "There was no evidence to suggest that patients who continued use were at increased risk of ocular hemorrhagic events, nor that those who discontinued use were at increased risk of medical events for which these medications were routinely prescribed." A recent multicentre audit of 55 567 cataract operations on patients taking antiplatelet and anticoagulant medications[89] concluded that "Clopidrogrel or warfarin use was associated with a significant increase in minor complications of sharp needle and sub-Tenon's cannula local anesthesia, but was not associated with a significant increase in potentially sight-threatening local anesthetic or operative hemorrhagic complications." It has been estimated that a randomized clinical trial would require 20 000 patients on anticoagulants to definitively determine if the medical risks of discontinuing therapy outweigh the surgical risks of continuing therapy.[88] Often patients are concomitantly taking Chinese herbal medicine and other supplements that may have anticoagulant properties or alter blood levels of anticoagulant medications. An International Normalized Ratio (INR) done preoperatively should be in the therapeutic range if injection block anesthesia is contemplated or for a combined procedure (e.g., trabeculectomy).
- **Unstable coronary artery disease (CAD) or uncontrolled hypertension.** In general, surgery should be delayed in these circumstances until a cardiologist and (or) an anesthesiologist has determined that the risk profile has returned to normal. If surgery cannot be delayed (e.g., for sight-threatening phakolytic glaucoma in a monocular patient), monitoring of oxygen saturation, blood pressure, heart rate, and electrocardiogram by dedicated operating room personnel with IV access, advanced cardiac life support certification, IV medication injection ability, and with access to an anesthesiologist are needed.
- **COPD.** Oxygen dependency must be maintained intraoperatively. $CO_2$-dependent breathers may do better with room air and drapes off the face. When cautery is used, the oxygen-enriched atmosphere beneath a closed, nonscavenged drape is a potential fire hazard.[90,91] Lifting the edge of the drape or using a scavenger system is recommended if cautery is to be used.
- **Tamsulosin HCl, alfuzosin HCl, and other alpha1-adrenergic blocking agents** may lead to IFIS.[92] Once the patient has been identified as a user, special surgical measures might be taken. Stopping these medications does not seem to reduce the risk of IFIS and may aggravate urinary obstructive problems.
- **"Caine" allergies.** Local anesthetics are either esters of benzoic and aminobenzoic derivatives (e.g., cocaine, benzocaine, procaine, tetracaine, butacaine) or amide-derivatives of xylidine and toluidine groups (e.g., lidocaine, mepivicaine, prilocaine).[93] Skin testing for amide and ester local anesthetics can include preservative-free lidocaine, which may identify patients allergic to the preservatives in amide anesthetics.[94] Methylparaben

preservative compounds are metabolized to para-amino benzoic acid , which is a potent allergen. Skin testing of methylparaben and metabisulphite is available. Patients allergic to amides, esters, and preservatives may require alternative therapies with diphenhydramine, opiates, general anesthesia, or hypnosis.[95]

- **Street clothes.** Many facilities allow patients to wear select items of personal clothing to preserve their dignity. No research has been published comparing field contamination or infection rates with and without personal clothing. The Operating Room Nurses Association of Canada recommends that "for outpatient surgery, patients may wear some of their own clothing, especially if the clothing does not interfere with the procedure and the procedure is short (e.g., cataract surgery). However, patients should still have their hair covered and be covered with clean linens."[96]

### *Anesthesiology service*

The workforce shortage of anesthesiologists in Canada is well recognized. Every model from no preassessment/no anesthesiologist/no monitoring to anesthesiologist preassessment and monitoring exists somewhere in our country. The consensus of this expert panel is that until a sufficiently sensitive and specific self-administered screening instrument exists, every patient should be preassessed before their first eye surgery by a health care professional (e.g., nurse, family doctor, anesthesiologist assistant, anesthesiologist, or ophthalmologist) and every patient should be monitored during surgery. Cataract surgery under topical anesthesia with oral sedation without anesthetic monitoring has been reported safe in appropriately selected, healthy patients with routine cataracts in a Canadian hospital setting.[97] The use of anesthesia extenders (nurses or respiratory technology assistants) has been documented to be cost effective and safe[98,99] with anesthesiologist input required in about 9% of cases.[99]

### *Pain-free surgery*

Anesthesia and sedation needs vary for patients undergoing cataract surgery. Surgery has been performed with no anesthesia.[100] Some cases can be done with hypnosis, acupuncture, or cold temperature.[100] Most surgeons use some form of anesthesia such as topical drops or gels or intracameral, sub-Tenon's, peribulbar, or retrobulbar blocks. Regional VII nerve blocks are sometimes also given. Sedatives, hypnotics, and opiate analgesics are sometimes also given alone or in combination via oral, sublingual, or IV routes.[100] General anesthesia is rarely administered.

Pain has been called the "fifth vital sign" and pain-free surgery is good for both the patient and the surgeon. Despite the use of modern techniques, 12% of patients still report mild pain and 9% report moderate to severe pain.[101] Breakthrough pain is often treated with IV adjuvant therapy with opiates, sedatives, or both. The prevalence of intraoperative medical events increases from 0.13% with topical anesthesia alone, to 0.78% with injection anesthesia, 1.20% with IV sedatives, 1.75% with IV opiates, and 4.04% with the combination of IV sedatives and opiates.[102] Pain often arises when an intraoperative complication occurs or during complicated procedures with prolonged operative times when it is essential to have a still and comfortable patient. In these circumstances, it is justifiable to administer these agents with their increased risk.

Surgeon and patient preferences are important. Surprisingly (and contrary to many contemporary surgeons' experiences), when given the choice, 72% of informed patients prefer regional block anesthesia to topical and more patients prefer oral to IV sedation.[103] Patient factors favouring topical anesthesia include monocular status, long axial length, external retinal hardware, and previous orbital surgery. Factors favouring injection anesthesia include language barriers, hearing impairment, tremor, posturing challenges, photophobia, blepharospasm, hyperkinetic eye movements, and combined and (or) complicated cases. Factors favouring general anesthesia include mental challenges, movement disorders, and phobic, anxiety, or panic disorders.

Injection anesthesia has rare (<1%) but significant risks of postoperative motility disorders, globe perforation, retrobulbar hemorrhage, brainstem anesthesia, and macular infarction.[104] Intracameral lidocaine injection with no preservatives has been reported to be safe, but has been shown to provide either a small but statistically significant adjunct to topical anesthesia[105] or no statistically significant reduction in intraoperative pain when compared with placebo.[106–109] The outcomes of visual acuity, functional impairment, complications, and patient satisfaction do not vary significantly with anesthetic technique.[104]

Discharge from care after cataract surgery should be based on set recovery room criteria including vital signs, mental status, nausea and (or) vomiting, and pain. Patients receiving oral, sublingual, or IV sedatives or hypnotics or opiate analgesics alone or in combination should have an accompanying person take them home after discharge. Pre-existing arrangements with an inpatient 24/7 monitoring facility should exist for eye surgical facilities without this ability in case a patient is not fit to be discharged.

#### RECOMMENDATIONS

24. Patients undergoing cataract surgery do not require routine preoperative medical testing [*Level 1A*[79]].
25. A preoperative assessment by a health care professional before the patient's first eye surgery should identify special pre-existing conditions such as:
    - allergies to latex, "caines," or povidone-iodine
    - MRSA or VRE positivity
    - a ventricular defibrillating device
    - diabetes mellitus, unstable CAD or hypertension, or COPD

- drugs that enhance urinary flow
- anticoagulant use
- long axial length
- external retinal hardware
- previous orbital surgery
- language barriers, hearing impairment
- tremor, movement disorders, or posturing challenges
- photophobia, blepharospasm, or hyperkinetic eye movements
- mental challenges
- phobic/anxiety/panic disorders [*Consensus*]

A repeat assessment should be performed with any significant change in medical status or if a year or more has elapsed since the first eye surgery [*Consensus*].

26. An INR done preoperatively should be in the therapeutic range if injection anesthesia is contemplated or for a combined procedure (e.g., trabeculectomy) [*Consensus*].
27. Given the small but significant risk of an adverse medical event (e.g., bradyarrhythmias, hypertension, oxygen desaturation) and the insufficient sensitivity of currently available self-administered questionnaires, preoperative evaluation and intraoperative monitoring of patients' oxygen saturation, heart rate, blood pressure, and pain level by a health care professional are recommended [*Consensus*].
28. The decision to use topical, injection, or another anesthetic technique with or without sedation should be a shared decision between the patient and surgeon [*Consensus*].
29. If topical anesthesia without IV opiate or sedative is administered, fasting is not necessary [*Consensus*].
30. Even in patients with iodine, IVP dye, or seafood allergies, sterile 5% povidone-iodine skin and conjunctival preparation are recommended. Alternative antiseptics should be used in patients with povidone-iodine dermatitis [*Consensus*].

## Day of surgery considerations

### *Biometry and intraocular lens calculations*

Accurate and targeted postoperative refraction involves 3 critical factors: (*i*) axial length determination, (*ii*) corneal power (keratometry), and (*iii*) appropriate IOL formula.

Axial length can be measured by A-scan ultrasonography (either applanation or immersion) or optical coherence biometry. Applanation ultrasonography, the most common biometric technique, is prone to corneal compression, is more technician dependent, and is less consistent and accurate when compared with immersion ultrasound.[110] Optical coherence measurements are accurate and consistent with immersion ultrasonography[111] but have additional advantages, including rapid testing time, the ability to measure to the point of fixation (particularly important in long eyes with posterior staphylomas),[112] and use in silicone-filled eyes.[113] However, the value of optical coherence biometry is limited in dense lens opacities or in patients who are unable to fixate properly.[114]

Corneal power may be ascertained from manual, automated, or topographic keratometry. For routine eyes, no specific keratometry technique has been shown to be superior. However, in eyes with previous corneal refractive surgery, these methods are unable to accurately measure the true central corneal power, thus necessitating the use of adjustments or other methods of corneal power measurements.

IOL calculations, most of which include a lens constant and 2 variables (axial length and corneal power), have evolved from empiric regression formulas to 3 generations of theoretical formulas utilizing geometrical optics. The latest generation of theoretical formulas, which vary the effective lens position as a function of axial length and keratometry, include Holladay,[115] Sanders–Retzlaff–Kraff/Theoretical (SRK/T), and Hoffer Q,[116] provide the greatest accuracy for most eyes.[117] Furthermore, later generation formulas such as Holladay 2[118] and Olsen formulas use >2 variables, including corneal diameter, ACD, and lens thickness. Preoperative refraction may provide further accuracy, particularly in extremely short or long eyes, or in eyes with disproportionate anterior and posterior segments. The Haigis formula,[119] which is a 3-variable, optimized formula that includes ACD, has also been found to be particularly accurate in these extreme eyes.[120] For further refinement, surgeons should consider personalized optimization of their lens constants based on their refractive outcomes.

IOL formulas calculate power for an in-the-bag placement of a posterior chamber IOL (PCIOL). In the event that endocapsular placement is not possible, and ciliary sulcus placement is performed (without optic capture through capsulorhexis), a decrease in the calculated IOL power is required. The degree of IOL power adjustment varies depending on the initial IOL power—typically a 1 diopter (D) reduction is required for most IOL powers. For IOL power >28.0 D, a 1.5 D reduction should be used; for powers from 9.5 D to 17.0 D, a 0.5 D adjustment should be used. IOL powers <9.5 D do not require a power adjustment.

### Recommendations

31. Either optical coherence or immersion ultrasonographic biometry should be considered to provide the greatest accuracy and consistency in determination of axial length [*Level 1B*[110,111]]. Applanation ultrasonography by a well-trained technician may provide similar accuracy [*Consensus*].
32. In order to provide the highest level of postoperative target refraction accuracy and consistency, latest-generation theoretical IOL formulas, including Holladay, SRK/T, and Hoffer Q should be used [*Level 1B*[117]].

33. For extremes of eye sizes, surgeons should use Holladay 2 and (or) Haigis calculations to obtain the best postoperative refractive accuracy [*Consensus*].
34. Considering variability in surgical technique, and thus outcomes, surgeons should consider personalized optimization of their lens constants based on their refractive outcomes [*Consensus*].
35. In the event a PCIOL is placed in the ciliary sulcus, a reduction in the IOL power, which is dependent on the initially calculated IOL power, is required and ranges from a 0 D to a –1.5 D correction [*Consensus*].

### *Intraocular lens calculations after refractive surgery*

Standard keratometry, as measured preoperatively for input into IOL formulas, typically extrapolates central corneal power based on paracentral sampling and assumes a set ratio between the anterior and posterior corneal curvature. Most IOL formulas also assume a certain effective lens position based, at least in part, on keratometry. These assumptions may lead to a postoperative refractive surprise (typically hyperopia after myopic treatment or myopia after hyperopic treatment) due to the change in the central cornea and the anterior/posterior ratio after refractive surgery (radial keratotomy, photorefractive keratotomy [PRK], laser in situ keratomileusis [LASIK] [myopic and hyperopic]). In this case, a variety of compensatory adjustments to the true corneal power can be made.[121] Some of the formulas for IOL calculations after refractive surgery require the input of pre–refractive surgery keratometry and (or) refraction or amount of laser vision correction, and include the clinical history method,[122] Feiz-Mannis,[123] Latkany,[124] and corneal bypass methods.[125] In the absence of pre–refractive surgery data, direct corneal measurements utilizing the hard contact lens method, topographical simulated keratometry (simK), or Scheimpflug central keratometry may be used.[126]

As the corrected effective corneal power is typically flatter after myopic refractive surgery for a given axial length, some IOL formulas may inaccurately predict the effective lens position. Therefore, the Aramberri Double-K correction should be performed.[127] This correction is built into the Holladay 2 formula and also does not need to be performed when using the Haigis formula.

Regardless of what adjustment or method is used, patients should be counselled as to the inaccuracy of IOL calculations after refractive surgery, and the potential for postoperative refractive surprises.

#### RECOMMENDATIONS

36. Surgeons should be aware that patients with prior corneal refractive surgery are at risk for postoperative refractive surprises after cataract surgery, and they should attempt to determine the true corneal power using an adjustment formula with pre–refractive surgery data and (or) alternative direct measures of central cornea, including simKs or Scheimpflug central corneal power. Ideally, multiple methods to ascertain the corrected corneal power and IOL power should be used [*Consensus*].
37. As the effective lens position is based on keratometry with many IOL formulas, a correction for the corrected flatter corneal power should be made in postmyopic LASIK or PRK eyes [*Level 3*[127]].
38. Patients with a prior history of corneal refractive surgery should be advised of the potential inaccuracy of postoperative target refraction achievement, regardless of method of IOL calculation adjustment utilized [*Consensus*].

### *Intraocular lenses*

Selection of a specific IOL is a multifactorial decision based on a variety of medical, optical, anatomical, lifestyle, and other variables and should involve adequate discussion with the patient.

The preferred location for implantation of an IOL during cataract surgery is a PCIOL placed in-the-bag. In the event of posterior capsule rupture, if an anterior capsule shelf and zonular apparatus is still intact, the PCIOL should be placed in the ciliary sulcus, with preference given to optic capture within the capsulorhexis.[128] Placement of a single-piece acrylic IOL in the ciliary suclus should be avoided due to concerns of iris chafing and uveitis-glaucoma-hyphema syndrome.[129] If there is no capsular support for sulcus placement, alternative options include the use of an anterior chamber IOL (ACIOL), iris-sutured PCIOL, or scleral-sutured PCIOL—all of which seem to provide similar visual outcomes.[130] If an ACIOL is used, appropriate sizing is critical in preventing complications involving the cornea, angle, and iris,[131] and a peripheral iridectomy should be performed.

Current choices of PCIOLs include rigid polymethyl methacrylate (PMMA) designs and foldable designs. Although best-corrected visual outcome in the long term appears to be similar between rigid or foldable designs, the larger incision required with a rigid lens may result in more induced astigmatism, reduced early postoperative visual acuity, more anterior chamber inflammation, delayed recovery, need for suture placement, and wound-related postoperative complications.[132] Due to the smaller incision required, foldable IOLs have become more commonly used, with a variety of materials, designs, and chromophores available. A PCIOL optic size of ≥6.0 mm is less dependent on centration, creates fewer dysphotopsias, and has a lower rate of posterior capsule opacification (PCO).[133]

Foldable IOL materials include silicone, hydrophilic acrylic (hydrogel), hydrophobic acrylic, and collagen/hydroxy ethyl methacrylate copolymer. Although small differences may exist, the latest generation of these materials

appears to be similar in terms of postoperative visual acuity, centration, and clinically significant uveal and capsular compatibility and should be selected based upon individual surgeon and patient factors.[134]

Foldable IOLs may be implanted using either forceps or an injector. Injector techniques provide rapid insertion, controlled incision size, and possible reduction of contamination and risk of infection.[135]

Most currently available IOLs have ultraviolet-filtering chromophores to provide protection against potential macular toxicity. Recently, blue-filtering and violet-filtering chromophores have been introduced in an attempt to provide further retinal protection based on population data and laboratory testing in acute environments.[136,137] However, the clinical value of blue or violet filtering is currently unknown and requires further study.

Traditional IOLs with spherical designs induce spherical aberration that, when added to positive corneal spherical aberration, can reduce contrast sensitivity, particularly in mesopic or scotopic conditions. Aspheric IOLs with negative spherical aberration can improve contrast sensitivity and quality of vision, resulting in improved mesopic and scotopic functions, including night driving.[138] The aspheric lenses currently available each correct or reduce a different amount of spherical aberration; the optimal amount to correct requires further study. There may be a role for customized spherical aberration correction depending on the patient's corneal spherical aberration.[139] However, caution must be exercised in using these lenses in patients at risk of decentration, as this may induce further higher-order aberrations.[140] As hyperopic LASIK induces negative corneal spherical aberration,[141] an aspheric IOL would not be indicated in these eyes.

Newer refractive IOL technologies, designed to provide further refractive correction of astigmatism and (or) presbyopia, offer further independence from spectacle correction postoperatively. Due to the increased need for precision and expertise, use of additional preoperative diagnostic technology and postoperative discussion and (or) adjunctive treatment are often required. The added complexity routinely involves additional preoperative patient education and discussion so that patients have appropriate expectations that can be achieved. Lifestyle questionnaires may be useful in ascertaining indications for these technologies.

Toric IOLs have been shown to reduce residual postoperative cylinder and improved uncorrected distance visual acuity when compared with non-toric IOLs.[142] Rotational stability, which is critical for effectiveness of the toric IOL, has been shown to be excellent with a 1-piece acrylic IOL.[143]

Presbyopic IOLs, which include multifocal and accommodating IOLs, aim to improve near and intermediate vision with resultant spectacle independence. Multifocal IOLs, which split incoming light into near and distance foci, provide improved near vision compared with monofocal IOLs.[144] Refractive precision with minimal residual postoperative cylinder is required for optimal performance of these IOLs. Potential pitfalls include reduced contrast sensitivity, haloes around lights, and glare. Multifocal IOLs can be divided into diffractive and (or) refractive designs, and some are now available with an aspheric design. Patient selection and motivation are felt to be critical in determining the appropriateness of a multifocal IOL and resultant surgeon and patient satisfaction.

Accommodating IOLs are designed to move with ciliary body contraction during accommodation, thus providing a nearer focus. Debate exists over the degree to which these IOLs can move, with studies showing limited accommodative ability.[145] One advantage over multifocal IOLs is the avoidance of haloes and lack of reduction of contrast sensitivity.

Monovision may also be a suitable and effective method to enhance near or intermediate vision, particularly if a patient has a history of successful monovision.[146] Appropriate discussion and potential for lack of tolerance in some patients needs to be considered when selecting full monovision as an option.

## RECOMMENDATIONS

39. Preferred PCIOL placement is within the capsular bag [*Consensus*]. In the event of a posterior capsule tear, placement of a 3-piece PCIOL in the ciliary sulcus (with optic capture within the capsulorhexis if possible) is preferred [*Consensus*]. In cases where inadequate capsular support is present, an ACIOL, iris-fixated PCIOL, or scleral-fixated PCIOL are all comparable options [*Level 2*[130]].
40. Foldable IOLs are preferred to rigid PMMA IOLs, as they are placed through smaller incisions, resulting in improved and more rapid final postoperative visual acuity, less early postoperative inflammation, and reduced surgically induced astigmatism [*Level 1A*[132]]. As such, foldable IOLs should be available to all patients having cataract surgery in Canada [*Consensus*].
41. Preference should be given to injecting foldable IOLs using an injectable cartridge system as opposed to forcep-folded IOLs in order to potentially lower the risk of bacterial endophthalmitis [*Level 3*[135]].
42. Aspheric IOLs should be considered to provide improved contrast sensitivity and functional vision, particularly in nighttime conditions [*Level 3*[138]]. In the presence of risk factors for decentration, such as torn zonules, or in the case of high astigmatism or posthyperopic LASIK, other lenses should be considered [*Consensus*].
43. Toric IOLs, which may be used in patients with regular corneal astigmatism, require consideration of surgically induced astigmatism, appropriate preoperative calculations, and steep axis markings, as well as careful placement of the IOL along the correct axis [*Consensus*].
44. Multifocal and accommodating IOLs, which

provide varying degrees of presbyopic correction, require careful patient selection, appropriate preoperative discussion and counselling, additional adjunctive preoperative diagnostic testing, and possible postoperative adjunctive treatments [*Consensus*].

### *Surgical technique*

Phacoemulsification provides significantly more rapid, improved, and stable visual acuity with fewer surgical complications compared with large-incision extracapsular cataract extraction (ECCE).[147] ECCE is, however, still performed in select circumstances, such as in the presence of an extremely advanced hard cataract.

Divide and conquer, stop and chop, and phaco chop are all effective nuclear removal methods. Thermal damage to the surgical incision, typically related to high ultrasound power coupled with loss of adequate irrigation flow at the incision, may result in poor wound closure and increased postoperative astigmatism. Phaco-chop techniques transmit less energy to the eye compared with divide-and-conquer techniques, although the effect on corneal endothelium in routine eyes seems to be comparable.[148] Recent advances in phacoemulsification technology include advanced fluidic control, hyperpulse and customization of power modulation, and torsional phacoemulsification. Although wound temperature appears to be reduced with these power modulations compared with continuous traditional phacoemulsification, no studies have determined the impact of these advances on clinical outcomes. Bimanual, sleeveless phacoemulsification through sub-1.2 mm incisions, utilizing a bare needle in one incision, and a second irrigating instrument in another incision, has been compared with coaxial phacoemulsification with mixed results, and has not achieved widespread adoption due to the surgical technique and instrumentation changes that are required, fluidic control, concern about wound trauma, and lack of availability of IOLs to fit through these micro-incisions. More recently, microcoaxial phacoemulsification, utilizing sub-2.2 mm incisions have touted the additional benefit of smaller incisions, with little change in surgical technique and greater availability of IOLs able to be injected through these incision sizes. No published studies have assessed clinical outcomes using these new technologies.

Surgical incisions should be placed to provide optimal access to the anterior chamber and be secure for intraoperative manipulations and fluidic balance within the eye. Postoperatively, incisions should ideally be watertight with minimal undesired impact on surgically induced astigmatism. Incision location, which may be scleral, corneal-scleral, or clear corneal, and may be placed at any meridian on the eye, is dependent on numerous factors, including patient anatomy, preexisting astigmatism, and surgeon preference. Although clear corneal incisions are easier to perform and obviate the need for conjunctival manipulation, there is some evidence that these incisions may increase the risk of endophthalmitis—although opposite findings have also been reported.[149] The discrepancy in findings may be due to surgeon variation in incision construction techniques and attention to watertightness at conclusion of the surgical procedure. Smaller incisions may close more easily, create less postoperative inflammation, and have less impact on surgically induced astigmatism.[150] Surgeons should err on the side of caution. If there is doubt about using a clear corneal incision, wounds should be sutured.

A continuous curvilinear capsulorhexis provides enhanced security of the capsular bag during manipulations of the crystalline lens, reduces the risk of an anterior capsular tear extending posteriorly, and aids in centration and endocapsular fixation of a PCIOL.[151] Complete overlap of the capsulorhexis over the IOL optic helps retard PCO.[152]

Hydrodissection reduces zonular stress during nucleus manipulation and helps prevent PCO and thus should be routinely performed.[153] The exception to this would be in the presence of a posterior polar cataract.

#### RECOMMENDATIONS

45. Small-incision phacoemulsification is recommended, as it provides faster, improved, and more stable visual acuity with reduced surgical complications compared with ECCE [*Level 1A*[147]]. Planned ECCE may be performed in select cases, such as in the presence of extremely advanced cataracts or hard lenses [*Consensus*].
46. Incision type selection and placement should be performed based on ideal construction, providing optimal access to the anterior chamber, watertight closure, and minimal undesired impact on surgically induced astigmatism [*Consensus*]. Smaller incisions are less prone to inducing corneal cylinder [*Level 3*[150]].
47. A continuous curvilinear capsulorhexis with overlap over the periphery of the IOL optic is recommended to aid in retarding PCO [*Level 1A*[152]].
48. Hydrodissection should be routinely performed (except in the presence of posterior polar cataract) to reduce zonular stress and facilitate cortical removal with reduction of PCO [*Level 3*[153]].

### *Intraoperative surgical adjuncts and scenarios*

#### *Ophthalmic viscosurgical devices*

Ophthalmic viscosurgical devices (OVDs) are essential adjuncts to cataract surgery and serve to maintain the anterior chamber and capsular bag during phacoemulsification and IOL implantation, protect the corneal endothelium, and manipulate or sequester tissues in the eye. OVDs can be broadly grouped into dispersives, cohesives, and viscoadaptives, with each class and OVD having its own set of unique behavioural characteristics. It is important that surgeons understand these characteristics for safe and effective use of

OVDs during surgery. Most OVDs are comparable in terms of corneal endothelial protection, with the exception of methylcellulose, which offers the least protection.[154] A viscoadaptive has specific advantages in space maintenance, but requires additional understanding of fluidics and removal techniques to ensure it is adequately evacuated from the eye, as incomplete removal can result in a significant IOP spike.

#### *Capsular dyes*

Capsular dyes, including indocyanine green and trypan blue, have been used to stain the anterior capsule in case of a white or mature cataract, or where visibility is compromised through a cloudy cornea. Trypan blue is safe to use in the anterior chamber and enhances visibility of the anterior capsule.[155]

#### *Capsular tension rings*

CTRs, which are placed within the capsular bag at any time after capsulorhexis, provide outward centrifugal expansile forces to assist in redistribution of zonular tension. The CTR is indicated for cases of zonular weakness, up to 4–6 clock hours of zonular dialysis, or generalized zonular weakness.[156] CTRs have been found to improve centration and tilt compared with no CTR in normal eyes,[157] and to reduce intraoperative zonular separation and capsular complications when used in pseudoexfoliation syndrome.[74] It is important to note that in cases of more severe zonular instability, the standard CTR may not be sufficient, and in those cases, a modified CTR or capsular tension segment should be used for scleral suture fixation.[158]

#### *Small pupil expansion*

Due to the inability to perform an adequately sized capsulorhexis and reduction of overall visibility, a small pupil is a risk factor for surgical complications. Comfort level with a specific pupil size varies from surgeon to surgeon. Various methods and devices for opening a small pupil have been described, with preference given to an atraumatic technique to reduce iris bleeding and pigment dispersion, IFIS, and postoperative atonicity. Prior to iris manipulation, posterior synechiae should be released. Methods to expand a small pupil include 1-handed or 2-handed pupil stretch, cutting the iris with mini-sphincterotomies, or creation of a sector iridectomy. Use of adjunctive devices includes expansion of the pupil with a highly cohesive OVD, iris retractors, and pupillary rings.[159] Few studies have assessed differences between these techniques and most seem equally effective.[160] Specific methods should be individualized based on ocular factors.

#### *Intraoperative floppy iris syndrome*

The association between tamsulosin (and other alpha1-adrenergic blocking agents) and IFIS, which is manifested by the triad of progressive miosis, flaccid iris, and iris prolapse, has been well described.[92] Patients should be screened before surgery to identify those who are at increased risk for surgical complications. Even those who have been on tamsulosin and have stopped using this drug are at risk. Methods for IFIS management can be categorized into pharmacologic (e.g., preoperative topical atropine, intracameral epinephrine, or phenylephrine); mechanical (e.g., iris hooks and pupillary ring devices); and the use of reduced flow parameters combined with combination cohesive and dispersive OVDs, most commonly a viscoadaptive.[161] Pupil stretching or cutting is not advised, as this may further aggravate the iris flaccidity.

### *Posterior capsule rupture and retained lens material*

Posterior capsule rupture occurs in approximately 1.9% of cases,[162,163] and the frequency of retained lens fragments is estimated at 0.3%–1.1%.[163,164] The visual outcome for these patients depends on the management of the vitreous and the retained lens fragments, as well as coexisting ocular pathologies. Cystoid macular edema (CME), persistent uveitis, PCO, endophthalmitis, glaucoma, retinal detachment, central retinal artery occlusion, and vitreous hemorrhage can all occur after capsule rupture and more so with retained lens fragments or invasive attempts to remove those fragments at the time of cataract surgery. One should never fish for dropped nuclear fragments.[163] Pars plana vitrectomy with removal of retained intravitreal lens fragments is beneficial for patients with persistent uveitis and glaucoma after phacoemulsification.[165] The optimal timing of vitrectomy has not been firmly established.[164] In a review of 155 eyes without preexisting ocular pathology, 87% achieved a best-corrected visual acuity of 6/12 or better.[162] However, poor visual outcome may occur secondary to retinal detachment and CME.[166]

#### RECOMMENDATIONS

49. OVDs are essential surgical adjuncts each with its own unique behavioural characteristics that should be understood for effective use. A viscoadaptive should be considered when maintaining space is difficult. Removal of all OVDs completely at the end of surgery is important to minimize the risk of postoperative IOP spikes. Optimal removal techniques differ for different classes of OVDs [*Consensus*].
50. Capsular dyes, particularly trypan blue, are safe and effective and recommended in assisting performance of capsulorhexis in cases with difficult visibility, white cataracts, or complex cases [*Level 3*[155]].
51. In cases of zonular weakness, including localized dialysis of up to 4–6 clock hours or mild generalized zonular weakness, the CTR should be used to provide enhanced intraoperative control, reduction of surgical complications, and improved postoperative IOL centration [*Level 2*[74]].
52. To reduce potential surgical complications, the small pupil should be expanded to an appropriate size, utilizing any number of techniques or

devices, depending on surgeon comfort level. While all seem comparably effective, preference would be to use as atraumatic a method as possible [*Consensus*].

53. Alpha1-adrenergic blocking agents (e.g., tamsulosin), and their association with IFIS should be elicited by history before surgery and prepared for by using any number of potential interventions, including preoperative atropine, intraocular epinephrine, lower-flow parameters, a viscoadaptive, iris retractors, or pupillary rings [*Consensus*].

## Complications and prophylaxis in cataract surgery

While cataract surgery is generally a safe and successful procedure, complications may occur at any stage during or after surgery and compromise the expected visual results for the patient.

### *Postoperative inflammation*

All intraocular surgery results in intraocular inflammation, which is a risk factor for corneal, trabecular, and retinal complications. Steroids and (or) nonsteroidal anti-inflammatory drugs (NSAIDs) are recommended in the perioperative period.

#### *Steroid therapy*

Steroid drops are usually started the day of surgery and then tapered down over 3–4 weeks. In one study, a single intraoperative sub-Tenon's capsule 40 mg triamcinolone acetonide injection was shown to have anti-inflammatory efficacy that was clinically equivalent to conventional 1% prednisolone eye drops in reducing intraocular inflammation, and was found to be as safe as prednisolone in terms of adverse effects.[167] However, concern exists about serious problems with steroid responders.

In eyes with quiescent uveitis that require systemic immunosuppression, it has been shown that a 2-week postoperative course of oral prednisone (0.5 mg/kg tapered after surgery) is superior to a single bolus of steroid (15 mg/kg 30 minutes preoperatively) in minimizing blood–aqueous barrier damage. The choice of specific additional steroid or anti-inflammatory treatment must be individualized based on the type of uveitis and the degree of postoperative inflammation and risk of potential systemic side effects from oral versus IV steroids. Such patients must be monitored more frequently and inflammation must be controlled aggressively in the postoperative period.[69,70] More studies are needed to define the ideal regimen.[168]

#### *Topical nonsteroidal anti-inflammatory drugs*

NSAIDs are often used perioperatively to prevent intraoperative miosis, ocular inflammation, and CME and to enhance analgesia. Despite those benefits, NSAIDs have been associated with some adverse events, including burning and irritation, superficial punctate keratopathy, and delayed wound healing (e.g., corneal melts).[169–171] Consensus on therapeutic ophthalmic NSAID use has not been established. Studies have shown decreased angiographic CME and better visual outcomes when NSAIDs are started 2 or 3 days before surgery and continued for 3 or 4 times a day for 3–4 weeks.[170,172] The decision to use NSAIDs with current phacoemulsification techniques must balance risks and benefits and surgeon's preference.

#### Recommendations

54. As all intraocular surgery results in intraocular inflammation (a risk factor for corneal, trabecular, and retinal complications), steroids, NSAIDs, or both are recommended in the perioperative period [*Consensus*].

### *Cystoid macular edema*

CME is the most common cause of decreased visual acuity after uncomplicated cataract surgery. The incidence is likely in the range of 1%–2% using modern cataract extraction techniques.[173] Many risk factors have been suggested including type of cataract surgery, light toxicity, vitreomacular traction, inflammatory mediators, age, iris colour, vitreous loss, integrity of posterior capsule, hypertension, and diabetes.[174,175] Pseudophakic CME typically takes 6–8 weeks to develop after cataract surgery. The diagnosis of clinical CME can generally be made on clinical examination with evidence of perifoveal cystic spaces and can be confirmed with use of fluorescein angiography to document the classic petaloid pattern of leakage mainly into the outer retina. It can also be diagnosed with OCT. The vast majority of cases from uncomplicated surgeries show spontaneous resolution. Topical NSAIDs have a positive effect on chronic CME.[176] Addition of topical or periocular steroids may augment the effectiveness of topical NSAIDs.[171] Steroids are effective in treating pseudophakic CME in uveitis patients who experience rebound inflammation. Periocular steroids, systemic steroids, and surgical intervention (e.g., Nd:YAG laser vitreolysis/vitrectomy) have been used when this occurs.[173,174] Prophylaxis with topical NSAIDs reduces the rate of early angiographic CME, but this difference is not significant at long-term follow-up periods.[176,177] It is unknown whether prophylactic treatment with NSAIDs translates to a decrease in the development of late-onset CME once the NSAIDs have been discontinued.

### *Endophthalmitis*

Endophthalmitis following routine cataract surgery is a potentially devastating complication that often results in severe vision loss. While it is rare (incidence ranges from 0.05% to 0.33%[178]), the incidence of endophthalmitis associated with cataract extraction has increased over the last decade.[179]

Sterile technique and avoidance of possible contamination have been the mainstays of prophylaxis for cataract

surgery. Most surgeons also prescribe topical antibiotics to be used following surgery. Some surgeons commence antibiotics prior to surgery. Possible sources of infection include bacterial flora in the conjunctiva and lids, nasolacrimal obstruction or the presence of Jones tube, contaminated instruments or solutions, improper draping at time of surgery, leakage of the wound, rubbing of the eye, immunocompromised host, and bacterial adherence to the IOL.[178,180]

The use of a drop of povidone-iodine 5% solution in the eye 5 minutes preoperatively has produced significant reduction in the rate of endophthalmitis.[178] Factors associated with endophthalmitis after cataract surgery may include wound location,[179] watertightness of the wound, type of cataract operation, concurrent eyelid procedure,[181] and posterior capsule rupture.[182] Additional risk factors include clear corneal incisions,[179,183,184] age >80 years, and surgery done in private centres.[185] Surgeons within 2 years of obtaining specialist qualification were more likely to have a case of endophthalmitis (Table 3).[181]

#### *Antibiotics*

Antibiotics to prevent endophthalmitis are currently being used in a variety of approaches: preoperatively, perioperatively (in the irrigation solutions,[186] subconjunctival,[181] intracameral[187]), and postoperatively.[181] Subconjunctival injection of antibiotics at the end of the procedure was shown to be beneficial for endophthalmitis prophylaxis.[181] A large, international cooperative study in Europe (European Society of Cataract and Refractive Surgeons [ESCRS] study of prophylaxis of postoperative endophthalmitis after cataract surgery) was designed to prospectively evaluate the prophylactic effect of intracameral cefuroxime (second-generation cephalosporin) and (or) perioperative topical levofloxacin (second-generation fluoroquinolone) on postoperative endophthalmitis after cataract surgery.[188] At the end of 2005, the incidence rate observed in the groups not receiving cefuroxime prophylaxis was almost 5 times higher than those that did.[189] Other studies have shown a rate of endophthalmitis similar to the ESCRS study intracameral group of 0.07%[189] but without any intraocular drugs (0.07%[183] and 0.076%[182]). The rate of endophthalmitis for the no-cefuroxime group in the ESCRS study was 0.33%,[189] which is surprisingly high. Cefuroxime appears safe in terms of local toxicity. Immunoglobulin E-mediated allergy to cefuroxime is rare.[190] The treatment achieves high aqueous concentrations even 1 hour after surgery.[190,191] Intracameral cefuroxime did not have a statistically significant effect on postoperative macular thickness compared with nonadministration of intracameral antibacterials.[192] There was a case report of severe anaphylactic reaction that occurred 5 minutes after 1.0 mg of cefuroxime was injected into the anterior chamber after routine phacoemulsification and IOL implantation.[193]

In an attempt to reduce the risk of endophthalmitis, some surgeons add vancomycin to the irrigating solution during cataract surgery[194] or inject vancomycin[195] or moxifloxacin[196] intracamerally at the end of surgery. As of yet there have been no published, controlled studies to determine the efficacy of these agents.

**Table 3—Factors associated with endophthalmitis**

| Factor | Effect on risk |
|---|---|
| Nonmodifiable factors | |
| Age >80 years[185] | Increased |
| Surgery performed in private centre[185] | Increased |
| Surgeon within 2 years of obtaining specialist certification[181] | Increased |
| Posterior capsule rupture[182] | Increased |
| Immunocompromised host[178] | Increased |
| Bacterial adherence to intraocular lens[178] | Increased |
| Modifiable factors | |
| Bacterial flora in conjunctiva and lids[178] | Increased |
| Contaminated instruments or solutions[178] | Increased |
| Improper draping[178] | Increased |
| Rubbing of the eye[178] | Increased |
| Povidone-iodine 5% drop in the eye 5 minutes preoperatively[178] | Decreased |
| Leakage of the wound | Increased |
| Concurrent eyelid procedure[181] | Increased |
| Clear corneal incisions[179,183,184] | Increased |
| Antibiotics | |
| Preoperative, topical | Decreased |
| Intraoperative, intracameral[187] | Decreased |
| Intraoperative, subconjunctival[181] | Decreased |
| Postoperative[181] | Decreased |

### RECOMMENDATIONS

55. In order to reduce the risk of endophthalmitis, all patients should have proper draping [*Level 3*[180]], preoperative management of lid margin disease [*Level 3*[197]], and use of 5% povidone-iodine [*Level 2*[180]].
56. Surgeons should be aware of their personal and institutional risk of endophthalmitis. If this rate is comparable to the current best published rates, there is no compelling evidence to warrant changing technique [*Consensus*].
57. If a surgeon's rate of endophthalmitis is higher than published norms, or when a higher risk of postoperative endophthalmitis is anticipated (such as when intraoperative complications occur), consideration should be given to supplemental intracameral or subconjunctival antibiotics [*Consensus*].

### *Posterior vitreous detachment*

The onset of postoperative posterior vitreous detachment is an important risk factor for development of retinal detachment after cataract surgery, particularly in eyes with lattice degeneration. The posterior vitreous detachment rate is higher after cataract surgery.[198]

### *Toxic anterior segment syndrome*

TASS is a sterile postoperative inflammatory reaction caused by a noninfectious substance that enters the anterior segment, resulting in toxic damage to intraocular tissue. The

process typically starts 12–48 hours after cataract surgery, is limited to the anterior segment, is always Gram-stain and culture negative, and usually improves with steroid treatment.[199] The primary differential diagnosis is infectious endophthalmitis.[200] Possible causes of TASS include intraocular solutions with inappropriate chemical composition, concentration, pH, or osmolarity; preservatives; denatured OVDs; enzymatic detergents; bacterial endotoxin; oxidized metal deposits and residues; factors related to IOLs such as residues from polishing or sterilizing compounds; and iris trauma.[199]

An outbreak of TASS is an environmental and toxic control issue that requires complete analysis of all medications and fluids used during surgery, as well as complete review of operating room and sterilization protocols. The use of reusable instruments should be minimized, and staff should be well educated and thoroughly instructed in proper cleaning and sterilizing protocols. Routine mechanical cleaning (including flushing of all cannulated instruments) and ultrasonic cleaning before sterilization should reduce the occurrence of debris on instruments. Cleaning solutions from the reusable instruments should be flushed with sterile deionized water after each cleaning step and before autoclaving.[201,202] This will also reduce the risk of transmission of prion diseases.[198,202,203] For the most current and detailed article on this topic, readers are referred to the American Society of Cataract and Refractive Surgeon's document entitled "Recommended practices for cleaning and sterilizing intraocular surgical instruments."[204]

Table 4 summarizes the factors favouring the differential diagnosis of TASS versus endophthalmitis.

**RECOMMENDATIONS**

58. A suspected case of TASS should be reported to the COS Eye Injury Registry at http://www.eyesite.ca [*Consensus*].

### *Corneal edema*

Corneal edema from inadequate endothelium pump function is one of the most common complications of cataract surgery resulting from mechanical injury, raised IOP, inflammation/infection, chemical injury, or concurrent eye disease. To reduce the incidence of corneal edema, phacoemulsification power and mechanical turbulence in the anterior chamber should be kept as low as possible, the endothelial surface should be avoided, and the endothelial cells should be covered with viscoelastic.[205]

**Table 4—Diagnosis of TASS versus infectious endophthalmitis[200]**

| Characteristics | TASS | Infectious endophthalmitis |
|---|---|---|
| Onset | 1–3 days | 3–7 days |
| Symptoms | Blurred vision | Pain, blurred vision |
| Cornea | Edema 1+ | Edema 2+ |
| Anterior chamber | Cells 1–3+ | Cells 3+ |
| | Fibrin 1–3+ | Fibrin variable |
| | Hypopyon 1+ | Hypopyon 3+ |
| Vitreous | Clear | Vitritis |
| Response to steroids | Positive | Negative |

Note: TASS, toxic anterior segment syndrome.

### *Neuro-ophthalmologic complications*

Neuro-ophthalmologic complications from cataract surgery are uncommon and include central nervous system toxicity, binocular diplopia, traumatic optic neuropathy, and ischemic optic neuropathy. These complications occur more frequently with retrobulbar anesthesia, as these blocks may be accidentally injected into the subarachnoid space with diffusion to the brainstem. Periocular injection may cause paresis or fibrosis of extraocular muscles, mostly if the injection is done into the muscle.[206] Anterior or posterior optic neuropathy can occur in the first 6 weeks after cataract surgery with or without periocular injection.[207]

Ptosis is an often overlooked complication of routine cataract surgery. It is frequently transient, but persistent ptosis may require surgical intervention. The causes include eyelid edema and hematoma, anesthesia myotoxicity, topical steroid use, and use of lid speculum or bridle sutures.[208] In routine cases with cooperative patients, topical anesthesia may be preferred to injection anesthesia in order to reduce the risk of nerve, muscle, and lid problems.

### *Descemet membrane tear and detachment*

Descemet membrane tear and detachment is a potentially very serious complication of cataract surgery. Small, localized detachments are rarely problematic, but persistent extensive detachments can affect visual acuity. The shift in favour of clear corneal incisions may be contributing to the increasing incidence of these detachments. Medical treatment is usually adequate since the detached membrane will often spontaneously reattach if given enough time to do so. Many surgical techniques have been described for intractable subtotal or total Descemet membrane detachment, including transcorneal mattress sutures with intracameral air injection, injection of 20% sulphur hexafluoride ($SF_6$) with air, injection of 100% $SF_6$, injection of 14% perfluoropropane ($C_3F_8$) at a nonexpansile concentration, and keratoplasty. Suggested preventive measures include using very sharp blades and increasing the size of the internal lip of the incision to reduce trauma, especially at the time of the IOL insertion.[209,210]

### *Surgically induced astigmatism*

Surgically induced astigmatism can result from thermal injury or from sutures that are too tight. The type and location of the incision also have an effect on postoperative astigmatism. While a clear corneal incision on the steeper meridian tends to reduce existing astigmatism slightly more than a temporal clear corneal incision, studies have shown no clinical benefit. More studies are needed to draw statistically significant conclusions.[211,212]

### *Intraocular pressure spikes*

IOP spikes after uncomplicated cataract surgery occur

mostly in the first 6 hours. The exact mechanism of IOP increases is not known, but is probably multifactorial. Causal factors include damage to the trabecular meshwork, use of viscoelastic substance, inflammation debris, hyphema, pupillary block, and peripheral anterior synechiae.[213] Adequate removal of the viscoelastic substance helps reduce the risk. Ocular hypotensive drugs can be used for prophylaxis. Agents that increase aqueous outflow, such as cholinergic agents, are the most beneficial in reducing postoperative IOP spikes.[214,215] Apraclonidine tends to be more effective than acetazolamide when used prophylactically.[216,217]

### *Suprachoroidal hemorrhage*

Suprachoroidal hemorrhage is a rare but potentially devastating complication of cataract surgery due to hypotony in the eye during surgery.[218] Multiple risk factors are involved in its pathogenesis. Patients at increased risk include older persons with a history of glaucoma, those with diabetes mellitus or high blood pressure, and those taking cardiovascular medications.[219]

Pain, shallowing of the anterior chamber, hardening of the eye, loss of the red reflex, and bulging of the posterior capsule should raise suspicion of suprachoroidal hemorrhage. Intraoperative treatment involves prompt closure of the wound and (or) drainage sclerotomy. Secondary anterior and posterior segment interventions are often required.[220,221] Poor prognosis factors include 4-quadrant suprachoroidal hemorrhage, ECCE, phacoemulsification conversion, retinal apposition, and retinal detachment.

## Postoperative considerations

### *Initial postoperative assessment*

Some authors have suggested that alternatives to the traditional postoperative day 1 review may be safe in some circumstances.[222–225] In addition, evidence suggests that initial review on the day after surgery may miss some early IOP elevations,[226] although no studies were found showing that treatment of these earlier pressure spikes leads to better outcomes. Proposed alternatives include deferral of first review until 2 weeks,[225] same-day examination by the surgeon, delegation of initial review to allied health professionals either in the clinic or at home, or telephone follow-up only.[227] In a randomized, controlled trial of 362 patients, patients reviewed later on the same day of surgery had no statistical difference in postoperative acuity at 2 weeks or postoperative quality-of-life scores at 4 months than those reviewed the next day.[222] However, another prospective study of 510 consecutive uncomplicated phacoemulsification surgeries found 4 cases of wound leakage at the day 1 visit, 2 of which required suturing.[223] Whether these wound leaks would have led to further complications and whether they would have been detected at a same-day review prior to discharge is unclear. Factors such as complicated surgery, comorbidity with glaucoma, and the use of heavier molecular weight ocular viscoelastic devices[228] make consideration of alternatives to the day 1 initial review more clearly inappropriate.

Given the low incidence of serious postoperative complications that require urgent intervention (e.g., wound leak, retained foreign body, TASS) larger studies with more power will likely be required to convincingly prove that reduced postoperative monitoring is safe. There is currently insufficient evidence to support the position that an early examination postoperatively can safely be eliminated. Current evidence also does not tell us whether initial postoperative review is best done later on the operative day or on the first postoperative day. However, since postoperative complications can occur at varying intervals following surgery, in all circumstances the surgeon must ensure that patients have access during the entire postoperative period to timely medical advice and assessment if problems arise. Surgeons should also clearly inform patients about symptoms that should warrant seeking urgent review. Components of each postoperative examination are listed in Table 5.

#### Recommendations

59. Patients undergoing phacoemulsification surgery should have a clear understanding of the expected postoperative course, the timeline for planned follow-up, and appropriate action if there are unexpected events in the postoperative course [*Consensus*].
60. There is currently insufficient evidence to recommend deviation from the current practice, in which patients undergoing phacoemulsification surgery have an initial postoperative review between 2 hours and 2 days after surgery [*Consensus*]. Plans for the timing and nature of the initial review after surgery should take into account the course of the surgery, surgical techniques used, comorbidities, and patient preferences [*Consensus*].

### *Subsequent postoperative assessment*

Assessment of the patients' final outcome should include visual acuity, refractive status, quality of life, and satisfaction level with the surgery. However, in cases where the patient returns to his or her optometrist for this examination, the information should be available to, and analyzed by, the operating surgeon in order to facilitate continuous quality improvement. Refractive stability after uncomplicated small-incision surgery (up to 3.5 mm) appears to occur as early as 1 week.[229]

#### Recommendations

61. In the absence of any of complications, a final assessment including refraction may take place after 2 weeks postoperatively for small-incision surgery (up to 3.5 mm), and after 6 weeks postoperatively for large-incision extracapsular

surgery. More frequent interval visits or delayed final assessment may be necessary depending on the complexity of the surgery, the presence of postoperative complications, the need for suture removal, IOP monitoring, or for patient reassurance [*Consensus*].

### Late complications

#### Posterior capsule opacification

Despite recent advances in both IOL design and surgical techniques that have decreased the incidence of PCO, it remains the most common late complication of cataract surgery. These advances have the common mechanism of enhancing the formation of a posterior capsular bend as a barrier to lens epithelial migration and associated capsular opacification.[230] Both acrylic and silicone lenses are associated with lower PCO rates than PMMA lenses. Lenses with a convex posterior surface have a lower rate than plano posterior surface lenses. Hydrophobic acrylic lenses have lower PCO rates than hydrophilic. A square posterior edge lowers the rate independent of lens material. Single-piece designs with wide, uniplanar haptic–optic junctions may reduce the effectiveness of the square-edge design.[231–236]

PCO rates are decreased by capsular bag implantation of the IOL and by implantation with 360° overlap of the IOL by the anterior capsular surface.[232] Vacuuming of the residual lens epithelial cells from the underside of the anterior capsule may increase the rate of PCO.[230] A recent study shows that careful hydrodissection can help to reduce the percentage of area of the central posterior capsule involved by PCO.[153]

#### Recommendations

62. In order to minimize the incidence of PCO, surgeons should carefully consider the size of the capsulorhexis [*Level 3*[232]], and the degree of the hydrodissection [*Level 2*[153]], as well as the material [*Level 1*[231,234]], and the optic edge design [*Level 1*[231,233,236]] of the IOL to be implanted.

#### Nd:YAG laser capsulotomy

Treatment of symptomatic PCO is by Nd:YAG laser capsulotomy. While this treatment is generally effective and well tolerated, complications of raised IOP, dislocation or subluxation of the IOL, intraocular inflammation, CME, and retinal tear and detachment have been reported. The risk of pseudophakic retinal detachment following Nd:YAG laser capsulotomy remains controversial. A number of studies have estimated the risk of pseudophakic retinal detachment as up to 4 times higher after Nd:YAG laser capsulotomy compared with those who did not have the laser procedure.[237] However, other studies, including a recent case-controlled study with over 45 000 cataract patients, suggest that subsequent Nd:YAG laser capsulotomy is not significantly related to retinal detachment, but the risk of retinal detachment after cataract surgery is significantly increased with posterior capsule tear, zonule dehiscence, retinal detachment in the fellow eye, axial length >23 mm, and male sex.[238,239]

Conflicting evidence, therefore, exists as to the relative risk of pseudophakic retinal detachment following Nd:YAG laser capsulotomy. In those studies that did show an increase in cumulative risk of pseudophakic retinal detachment following Nd:YAG laser capsulotomy, there did not appear to be an association with laser parameters, capsulotomy configuration, or interval between cataract surgery and Nd:YAG laser capsulotomy.[237] Some authors have advocated for closer follow-up and prophylactic photocoagulation of preexisting retinal breaks, particularly in high-risk eyes.[237]

#### Recommendations

63. Nd:YAG laser capsulotomy is indicated for the relief of visual symptoms attributable to PCO. Decision to proceed to Nd:YAG laser capsulotomy for PCO should take into account the possibility that Nd:YAG laser capsulotomy may increase the risk of pseudophakic retinal detachment, particularly in high-risk eyes [*Level 3*[238]].

#### Late in-the-bag intraocular lens dislocation

Late in-the-bag dislocation of the IOL has been reported recently with apparently increasing frequency. This complication occurs, in many cases, years after surgery and is attributable to progressive loss of zonular support. Reported associations are preoperative zonular weakness (e.g., trauma, pseudoexfoliation, high myopia, previous vitreoretinal surgery), surgical trauma to the zonules, capsule contraction syndrome, and postoperative trauma.[240]

#### Pseudophakic retinal detachment

Pseudophakic retinal detachment is one of the most serious late complications of cataract surgery. While changes over the years in cataract surgery technique from intracapsular to extracapsular methods have lowered the cumulative risk of retinal detachment following cataract surgery, it appears that the cumulative risk following phacoemulsification is similar to that following ECCE. This risk is consistently estimated by a number of studies as 4–5.5 times higher at 10 and 20 years than the population not having surgery. Risk factors for pseudophakic retinal detachment include male sex, younger age, myopia,

**Table 5—Components of each postoperative examination[24]**

| Evaluation | Details |
|---|---|
| Interval history | Postoperative medications |
| | New symptoms |
| | Self-assessment of vision |
| Measurements | Visual function (acuity, pinhole testing) |
| | Intraocular pressure |
| Examinations | Slit-lamp biomicroscopy |
| Consultations | Counselling/education for patient or caregiver |
| | Management plan |

increased axial length, posterior capsule tear or vitreous loss at the time of surgery, and history of retinal detachment in the fellow eye.[241,242]

**RECOMMENDATIONS**

64. Patients undergoing cataract surgery, particularly those with risk factors for retinal detachment, must be made aware of the risk of subsequent retinal detachment and should be counselled on the symptoms of retinal detachment to ensure timely diagnosis and treatment [*Level 1*[243]].

*Dysphotopsias*

Dysphotopsias, or unwanted visual effects, after uncomplicated cataract surgery are common. The incidence of dysphotopsias following surgery varies substantially depending on whether patients are asked about them (20%–77%)[244–247] or are left to self-report (0.2%–1.5%).[245,248] The incidence also decreases sharply with increasing time after surgery.[244,249] Dysphotopsias can be divided into positive and negative effects. Positive dysphotopsias are the result of introducing unwanted patterns of light onto the retina, producing visual effects such as glare, haloes, flashes, streaks of light, etc. Negative dysphotopsias are the results of light being prevented or blocked from reaching certain parts of the retina, manifesting most commonly as a dark temporal crescent in the patient's visual field.

The risk of pseudophakic dysphotopsia should be considered (among many other factors) when choosing an appropriate IOL for cataract surgery,[250,251] and should be balanced with the risk for development of PCO.[252] IOL materials and designs have evolved, partly in an effort to reduce the incidence of PCO postoperatively. Some of these changes have been shown to increase the incidence of dysphotopsias. Subsequent modifications in IOL design were made with this in mind.

Both clinical and theoretical ray-tracing studies have suggested factors that affect the incidence and severity of dysphotopsias. Factors suggested to be associated with increased incidence or severity of positive dysphotopsias include square anterior edge,[246] smooth optical edge (vs textured or frosted),[249] reduced optic size,[244] 3-piece construction,[252] and increased anterior curvature and (or) unequal biconvex construction.[253,254] The data regarding the effect of material with a higher refractive index are conflicting.[244,251] The mechanism of, and factors associated with, negative dysphotopias appear to be more elusive.[255]

Despite the apparent persistence of pseudophakic dysphotopsias when patients are questioned as long as 1 year after surgery,[245] the prevalence of significant spontaneous complaints is very low.[244,248] It has been suggested that the initial treatment of persistent dysphotopsias may be counselling, time, and reassurance. In the event that this approach is ineffective, however, nighttime pupil constriction, IOL exchange (for size, material, or design),[248] or piggyback IOL implantation[256] have been suggested and each has anecdotal reports of resolution of symptoms. Caution should be exercised to ensure that complaints of dysphotopsia are not incorrectly attributed to PCO, as opening the posterior capsule with Nd:YAG laser capsulotomy makes the option of subsequent IOL exchange, should it become indicated, much more difficult.

**RECOMMENDATIONS**

65. The risk of pseudophakic dysphotopsia should be considered, along with many other factors, when choosing an appropriate IOL for cataract surgery [*Consensus*]. These risks should be balanced with the risk for development of PCO [*Level 3*[252]]. In those patients who do experience dysphotopsias postoperatively, time and reassurance should be used prior to considering other more invasive methods of treatment [*Consensus*].

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