

Advances in Cataract Surgery

a report by

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Cataract surgery transformed radically this past century. From cocaine topical anesthesia, immobilized patients, and extracapsular technique on ‘ripe’ cataracts we advanced to retrobulbars, sutured incisions, and intracapsular technique. Today’s techniques recapitulate those of old, with topical anesthesia and intact capsular bag support of implants enabling virtually instant visual recovery, minimal discomfort, and immediate resumption of full activity, often spectacleless, with unparalleled safety.

The ability to remove the cloudy lens through a small, stable incision, leaving the zonular capsule complex intact combined with technology to refocus light rays clearly onto the retina facilitate today’s extraordinary outcomes. These results are often achieved even in eyes with compromised anterior segment anatomy.

Technique

Phacoemulsification, capsulorhexis with its subtleties and viscoelastics permit the removal of any stage cataract through a tiny self-sealing clear corneal incision. Advanced incision architecture nearly eliminates induced astigmatism and permits immediate stable post-operative refractions. Reliable intracapsular implantation enhances accurate implant power calculation.

The Pursuit of Spectacle Freedom

Intraocular lens (IOL) selection formulae have been evolving with the realization that eyes are not always proportional in size. By incorporating white-to-white measurement into calculations traditionally only including axial length and corneal shape, the significant percentage of myopes and hyperopes with normal size anterior segments are accounted for, thereby reducing outliers.

Two lenses are rarely piggybacked since high hyperopia can now be addressed with aspheric IOLs measuring up to 40 diopters. The potential benefit of two lenses must be weighed against the risk of inter-lenticular opacity, which could defy yttrium aluminum garnet (YAG) laser correction. This incidence may approach zero when the capsulorhexis does not cover the IOL edges

or when one lens is in the bag and the other is in the sulcus. Piggybacking proves useful to correct refractive surprises without a lens exchange, thereby minimizing the risk of bag rupture and inaccurate calculation. Existing low plus and minus power foldable IOLs provide an almost unlimited range of correction. Narrow-profile sulcus lenses minimize the risk of pigmentary dispersion. Low-power multifocal or pseudo-accommodative lenses to piggyback over pre-existing monofocal lenses for pseudophakic presbyopia remain rarely used but available.

Pre-existing refractive error is addressed by proper lens selection for spherical power and treatment of astigmatism. Toric lenses provide an alternative to corneal incisional techniques such as astigmatic keratotomy. In the majority of cases, with pre-operative topography and intra-operative keratoscopic confirmation, both methods are predictable up to two diopters. ‘Bioptics’—intentionally planning laser-assisted *in situ* keratomileusis, (LASIK) combined with IOL implantation—can be used for higher degrees of astigmatism. Healing is rapid, and complications few.

New IOL technology neutralizes the normal cornea’s positive spherical aberration improving contrast sensitivity and modulation transfer function. Theoretically, with wave front analysis, individual customized implants may become possible. A new polymer that redistributes molecules when exposed to a particular wavelength of light—known as light adjustable lens technology—may allow post-operative adjustment of implants’ shape and power to eliminate higher and lower order imperfections post-operatively.

A blue filtering chromophore in addition to the routine IOL ultraviolet blocker has been introduced. This subtle and typically imperceptible hue resembles a 40–50-year-old’s human crystalline lens brunescence, but features an absorption curve closer to that of a four-year-old than the clear ultraviolet (UV) standard lens provides. It will take years to ascertain whether this will significantly protect macular health in the long-term but it may rapidly become standard care.

Baby boomers’ presbyopia frontier has been breached

with monovision through contact lenses and refractive procedures. Some surgeons espouse pseudophakic 'blended vision' with one eye focused 1.50 diopters near to achieve relative spectacle independence but pseudo-accommodative lenses provide the best range of uncorrected vision without compromising depth perception. Emerging technologies are anticipated to eliminate the disadvantages of simultaneous vision from diffractive and refractive multifocal strategies and provide true accommodation eliminating the neuro-adaptation requirement of the most popular lenses today.

Anesthesia

Although rare, the risks of intraconal anesthetic injection were reduced with peribulbar (extraconal) injection. Remaining risks were further minimized by sub-Tenon's cannula anesthesia and topical anesthetics. Once the surgeon forgoes akinesia—requiring keen pre-operative assessment and heightened skills of patient communication—instant functional recovery and reduced anesthetic complications occur. Topical with intracameral preservative-free lidocaine anesthesia keeps surgery comfortable, minimizes the need for sedation and enables procedures for even the most fragile patient with appropriate monitoring. When combined with clear corneal incisions risk of significant bleeding is essentially eliminated. Anticoagulants need not be discontinued, and patients can resume vigorous activity without risk of hemorrhage or iris prolapse. I used to dread anesthetic injections and post-operative occlusive patches for monocular patients.

Complications

Endophthalmitis's occurrence of 1:1100 since the advent of extracapsular surgery has possibly recently increased.¹⁷ Some associate this apparent increase with the rise of clear corneal sutureless incisions, yet many believe that properly constructed incisions remain safe and stable. The rise of bacterial resistance may be contributory. Although uncommon, this one seemingly uncontrollable, potentially devastating complication traditionally precludes same-day bilateral surgery.

Ophthalmology remains surgical prophylaxis's stepchild. In general surgery, statistically confirmed classic treatment reduces post-operative infection. Appropriate prophylaxis requires the optimal drug for likely pathogens must be adequately concentrated in the target tissue for the vulnerable period, the interval beginning just before incision until after the wound closure. In the past no systemic antibiotics, the traditional route for prophylaxis, could achieve adequate ocular levels due to the blood-retinal barrier. Therefore, no logical standard of care had been established. Consequently, practices

vary from no prophylaxis to topical, intracameral irrigation, or subconjunctival injection usually at the conclusion of the case.

Recently, a multicenter study showed a five-fold reduction in the incidence of endophthalmitis with the use of intracameral antibiotic. Fluoroquinolone (FQ) antibiotics achieved rapid acceptance because of their ability to penetrate both blood-retinal barrier and cornea and their broad-spectrum activity against the usual pathogens. Owing to the pure tonnage, agriculture and general medicine's use of second- and third-generation FQs led to a rapid increase in gram-positive resistance. Currently, fourth-generation FQs provide better coverage and require two mutations of the DNA gyrase for organisms' resistance. These antibiotics sterilize the ocular surface and penetrate aqueous and ciliary body tissue better than any antibiotic historically. Improved defenses and greater emphasis upon proper wound construction may result in a reduction of infection in the near future.

Other complications associated with cataract surgical technology are consistently falling. The on-going refinement of phacoemulsification machines in controlling ultrasound delivery and improved understanding of fluidics and their effect on the intraocular environment are advancing rapidly. Reduced tube and cassette compliance and fluid restrictors, more sophisticated software, and our ability to work in a nearly closed system help overcome surge and turbulence challenges. Many strategies use non-continuous ultrasound energy including hyperburst and hyperpulse at the millisecond level. Both on and off times can be varied to create different duty cycles, which increase efficiency and virtually eliminate thermal damage to tissues. A recent addition to our toolbox is torsional phacoemulsification. The to and fro motion of the ultrasound tip results in improved followability and further reduction of thermal damage. The efficiency of Torsional phaco efficiency at 32,000hz exceeds that of sonic energy at 100hz in a torsional plane used in synergy with traditional ultrasound. Cavitation and its controversial effects may be reduced as well. New research is starting to shed light on the issue of free radical production and its effect on corneal endothelium. Laser cataract disruption has been abandoned while Aqualase—pulsed jets of warm fluid—is touted as more capsule-friendly for soft cataracts or refractive lens exchange. Protective improvements afforded by viscoelastics with different properties maintain clear corneas, protect iris architecture, minimize inflammation, and further optimize recovery. Cohesive viscoelastics hold space under conditions of low shear and are easy to remove. Dispersive viscoelastics enable reliable coating of structures creating better barriers and the ability to compartmentalize. The properties of the agents

can now be matched to the tasks at hand. A unique viscoadaptives substance, Healon 5, increases viscosity and varies its properties according to turbulence and the demands of the situation.

New maneuvers allow us to work through small pupils without damaging their function. Iris retractors' gentle stretch of the sphincter combined rarely with pupillary membrane peeling or minute sphincterotomies can provide a 4–5mm pupil. This size is adequate for most techniques. Divide and conquer disassembly technique still works; however, other approaches like horizontal chop, phaco flip and phaco pre-chop reduce removal time and energy. Vertical phaco chop allows sectioning of the nucleus without sculpting or placing instruments beyond the continuous curvilinear capsulorhexis.

The bimanual (actually, biaxial) phacoemulsification debate waxed and waned again. Non-continuous ultrasound strategies reduce thermal wound damage, which permits coaxial irrigation sleeve removal. Lens material is evacuated through a bare needle with side port irrigation provided most often with an irrigating chopper. Other names proposed for this technique are 'microincision phaco' and 'phaconit.' Although cataract removal occurs through two 1.2–1.4mm incisions, they tend to be stressed by the round bare metal causing less secure closure. Less than 2mm incisions are now possible with coaxial methods. Improved fluidics and ability to insert modern implants makes this increasingly likely. Newer nuclear disassembly techniques and improved visualization reward temporal incision surgeons with reduced capsule rupture, vitreous loss and associated sequelae.

Advances in vitreous loss management contribute to better outcomes. Increasing evidence suggests pars plana incisions for anterior vitrectomy is the most efficient approach with the best results. This is graphically obvious with Kenelog suspension 'particulate marking' of the vitreous. Once purified of preservatives, this steroid suspension is irrigated into the anterior chamber. It preferentially adheres to the vitreous. This resembles 'throwing a sheet over a ghost', making the presence and the behavior of the vitreous visible. This avoids the inadvertent strand of vitreous being left in the wound for later discovery. Effectively anticipating this complication can lead to gratifying outcomes.

Thorough viscoelastic removal technique reduces possible post-operative pressure rise. Clear corneal approach avoids breaching conjunctiva protecting pre-existing filtering blebs and improving outcomes for future surgery, as well as other conjunctival associated problems like dellen decline. Patients at risk for post-operative pressure spikes can be managed with immediate post-operative

administration of acetazolamide, lately shown to be even more effective than previous strategies. There is a modest improvement in controlled glaucoma cases after modern cataract removal. This allows conservative indications for combined glaucoma-cataract surgeries. Trabeculectomy remains the standard of care. Endocyclophotocoagulation, when combined with phacoemulsification as well as non-penetrating filtering procedures like viscocanalostomy remain controversial.

The value of intra-operative maintenance of relatively stable intraocular pressure is being increasingly recognized. Periods of zero pressure may promote choroidal effusion, cystoid macular edema, and suprachoroidal hemorrhage. Anterior chamber instability and trampolining stresses zonules and the vitreous base contributing to later complications like retinal tears, detachment, and unpredictable IOL centration.

Rehabilitation

Concern persists over eye rubbing and surface contamination immediately post-op and until any epithelial defect seals. Otherwise, there is little demand for lifestyle change post-operatively. Post-operative topical drop regiments depend of patient compliance. Future implantable time-release implants may eliminate even this annoyance.

Certain intraocular lenses, due to their chemical composition or configuration, may affect the incidence of late posterior capsule opacification (PCO) and secondary YAG laser capsulotomy. Only 5% capsule opacification occurred in a three-year follow up with current acrylic designs as opposed to a 40–70% rate with earlier polymethyl-methacrylate (PMMA) and some silicone lenses. Third-generation silicone may enjoy a low rate similar to acrylic materials. Seemingly benign, PCO increases the potential for retinal detachment, rare pressure problems and economic expense. It also limits viable research into filling the bag with substances emulating the natural crystalline lens. Emphasis continues on the development of lens designs and materials that reduce lens epithelial cell migration and fibrotic capsular changes. There is almost universal appreciation of the importance of covering the optic's edges with the anterior capsulorhexis lip to allow the sandwich phenomenon to seal the bag. Meticulous cortical clean-up is essential. For a period, vacuuming the anterior capsule flaps was considered; however, current evidence suggests that cells on the flaps actually facilitate the adherence of the capsule to the lens optic thereby decreasing PCO. Un-vacuumed capsules result in more anterior fibrosis with lens epithelial transformation induced by contacting implant material. Only the equatorial cells can multiply and migrate. A new technology, not in clinical use, seals the bag's interior

permitting irrigation of a substance toxic to lens epithelium without affecting the surrounding environment. Some, however, question whether the epithelium contributes to healthy basement membrane which maintains capsular and even zonular integrity. Overcoming the sequelae of capsular opacity will be a major factor in advancing the art of cataract surgery and particularly the acceptance of refractive lens exchange as a dominant technique in the refractive market of the future. Routine posterior continuous curvilinear capsulorhexis with IOL optic capture through the posterior capsule may be the most promising way to eliminate opacity of both anterior and posterior capsule but is technically challenging and not widely practiced.

Pediatric Cataract

Preservation of sufficient capsule for anticipated secondary IOL implantation has been standard for decades, however primary intraocular lens implantation has become the norm in an ever-younger population. Over the age of two it is standard of care and remains controversial below that age.

Continuous curvilinear capsulorhexis (CCC) in elastic capsules is challenging but is a prime factor in IOL stability in children. Posterior CCC may obviate the need for planned anterior vitrectomy, which is traditionally used to disrupt scaffolding for visual axis opacification. Some advocate optic capture through a posterior capsulorhexis, maintaining the haptics in the bag.

Aphakia is becoming extinct as it is now possible to implant safely, primarily or secondarily, in virtually every situation. The choice of a modern open loop anterior chamber lens or a sutured posterior chamber lenses are viable options. Scleral fixated sutured lenses are less popular due to erosion or dissolution of sutures over time. Iris fixation is becoming more frequent.

Challenging Cases

As success in achieving in-the-bag IOL placement and safe phaco depends upon the integrity of CCC, the white cataract remains challenging. Due to the absent red reflex and the further obscuration of view caused by release of intumescent lens milk, various techniques evolved to promote visualization of the anterior capsule. Highly viscous cohesive viscoelastic clears the chamber and maintains it, preventing convexity which promotes tear extension. Capsular dyes are the standard of care. Indocyanine green is rarely used since the FDA approval of trypan blue. This technique all but eliminates the increased complication rate.

Even densely brunescant cataracts escape extracapsular

surgery as third-generation technologies have ample power to cut any nucleus. Newer phaco needle designs also contribute efficiency with shape, size, angle, and wall configuration. Mechanical forces applied by instruments in the non-dominant hand, and software allowing non-continuous ultrasound strategies reduce the raw phaco energy required for even the most mature black cataract.

Disordered anatomy due to trauma or collagen disease is becoming less of an impediment to a perfect outcome as a plastic spring-like device known as a capsular tension ring has become widely used. Expanding the bag with weakened zonules redistributes forces when some zonules are broken or missing. Modified rings serve as an artificial zonule when sewn to sclera stabilizing or re-centering a subluxated lens. Though controversial, it has been suggested that most pseudoexfoliation patients may deserve such a ring.

Artificial iris diaphragms have been introduced to eliminate diplopia and debilitating glare for traumatic or congenital aniridia and colobomas. New avenues are being explored with prismatic and telescopic implants for macular degeneration patients. These new devices, however, are very slow to become available in the US due to the double-edged sword of the regulatory process.

Conclusion

The growing realization that the fewer instruments used, the more effective and elegant each move, the more physiologic the pressure and chamber relationships, and the briefer the surgical intervention, the better the outcome, drives many surgeons to streamline techniques. Economics direct surgery toward the more efficient surgeon; fewer surgeons perform more cases. One rigorous model estimates fewer than 1,000 cataract surgeons for the whole US.

This overview of the state of the art of cataract surgery reveals a success story exceeding expectations. The procedure has become so safe and effective that lens based refractive options are gaining acceptance as a viable alternative to corneal surgery. It is a daily joy to apply these techniques for our patients, but there is still room for improvement. The high success rate should increase as the technology curve holds its own. Cost concerns and access to care will hopefully improve, as there are still millions of patients worldwide blind from cataracts. The means not only to treat cataracts but to prevent them should be found so we can move on to conquer new challenges in ophthalmology. ■

A version of this article containing references can be found in the Reference Section on the website supporting this briefing (www.touchsensorydisease.com).