Advances in Cataract Surgery

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Abstract

Cataract surgery is a technique described since recorded history, yet it has greatly evolved only in the latter half of the last century. The development of the intraocular lens and phacoemulsification as a technique for cataract removal could be considered as the two most significant strides that have been made in this surgical field. This review takes a comprehensive look at all aspects of cataract surgery starting from patient selection through the process of consent, anaesthesia, biometry, lens power calculation, refractive targeting, phacoemulsification, choice of intraocular lens and management of complications such as posterior capsular opacification as well as future developments. As the most common ophthalmic surgery and with the expanding range of intraocular lens options, optometrists have an important and growing role in managing patients with cataract.

Keywords

Advances

Cataract surgery

Intraocular lens

Phacoemulsification

Introduction

The origins of cataract surgery can be traced back to 800 BC when cataracts were treated by a method called 'couching' whereby the hypermature cataract was dislodged into the posterior segment of the eye by blunt force on the eye. No lens was implanted and the eye was left visually aphakic (i.e. no lens in the visual axis). Apart from a large incision cataract extraction, nothing much changed till the middle of the 20th century when intraocular lenses were introduced by Harold Ridley. Ridley observed that segments of Perspex from the crashed windshield of aircrafts in the eyes of Second World War RAF pilots were inert. This observation led him to develop a lens design to replicate the structure and function of the crystalline lens before it became cataractous.[1] Interestingly, the material that he used, polymethylmethacrylate (PMMA), is still being used widely in lens implants although other biomaterials like acrylic and silicone have taken over in the more developed countries. Advances in lens design are overcoming the risk of posterior capsular opacification as well as reproducing attributes of the crystalline lens like asphericity, accommodation and ultraviolet (UV) barrier function.

Surgical manipulation for cataract surgery can also induce changes in the corneal curvature, damage endothelial cell count and function as well as have effects on the iridocorneal angle. Some of these collateral effects could have a detrimental effect on the visual outcome.

Latest technology and instrumentation have made a reduction in the incision size possible, thereby leading to a more rapid stabilisation of the wound. Software refined phacoemulsification energy delivery, enhanced fluidics as well as ocular viscoelastics have facilitated safer cataract removal with a much reduced endothelial injury. Biometric technology and software have enabled a very high degree of accuracy in the prediction of the final refractive outcome. Intraocular lens designs have risen to the challenge of being able to be implanted through increasingly smaller incision widths. Additionally, newer intraocular lenses are striving to address issues beyond merely refractive status, like accommodation and UV protection.

Many of the technological innovations are funded and developed by the industry. A lot of information is commercially sensitive, especially those areas which are in development. Some of the very latest advancements in technology are yet to undergo the scrutiny of unbiased, peer-reviewed research.

This review has been based on literature accessed from the Medline database, non-peer reviewed journals, industry literature, personal communication and personal experience. The aim is to provide the reader with a comprehensive review of the latest advancements in cataract surgery highlighting the highest level of evidence obtainable in each individual regard.

Patient selection and managing expectation

Cataract is a poorly defined concept within ophthalmology especially during the early stages of opacification. If Snellen visual acuity were to be the mainstay of judging the visual disability of the patient, many patients would miss out on the benefits of surgery. Likewise if all the natural properties of the crystalline lens are not taken into effect, the outcome could be disappointing. For example a patient could lose almost all accommodation, have reduced unaided acuity due to induced astigmatism, lose contrast sensitivity due to spherical aberrations or experience worsening of age related macular degeneration due to the loss of the UV barrier function of the natural lens.

A comprehensive history encompassing the nature of visual disability (e.g. night time, driving, interference with specific nature of work or hobbies); prior ocular conditions (including history of amblyopia); relevant family ophthalmic history; medical conditions, drug intake and allergies should be sought and recorded. Current, refraction in both eyes is useful to plan refractive outcome post operatively especially with unilateral cataract. Ocular risk factors for surgery and co-morbidity should be assessed (see below). Their identification should lead to appropriate precautions and or surgical modifications, to minimise the risk of post-operative complications.

[TABLE] Ocular risk factors for surgery

- Infection (e.g. severe staphylococcal blepharitis, dacryocystitis)
- Ocular surface disease (e.g. ocular mucous membrane pemphigoid)
- Prior ocular surgery (e.g. trabeculectomy, keratoplasty)
- Corneal opacification (e.g. trachoma, previous keratitis, dystrophies)
- Decreased endothelial cell count (as in Fuch's dystrophy)
- Chronic, recurrent uveitis
- Keratitis (especially herpes simplex)
- Glaucoma
- Fuchs heterochromic uveitis
- Pseudoexfoliation syndrome
- Zonular weakness (e.g. Marfan's syndrome, homocystineuria)
- Previous angle-closure
- Previous vitrectomy
- Previous ocular trauma
- Posterior polar cataracts (with pre-existing capsular rent)
- High myopia, nanophthalmos
- Drugs (e.g. Tamsulosin increases the risk of intra-operative floppy iris[2])

Informed consent

Cataract surgery is very successful in the majority of cases. Topical anaesthesia, day-case surgery, shorter operating and recovery times as well as a remarkable improvement in vision have often trivialised the risks associated with the procedure. It should not be overlooked that cataract surgery is still regarded as highly complex alongside other major surgical specialities like neurosurgery or cardiothoracic.

Data from a multi-centre audit of 55, 567 cataract operations performed across 12 hospitals in the UK (conforming to the Cataract National Dataset as defined by the Royal College of Ophthalmologists) showed that 99.7% of cataract surgery was performed by phacoemulsification (2001-2006). The previous Department of Health sponsored National Cataract Surgery Survey performed during 1997-98 showed a much lower rate of phacoemulsifcation.[3] The latest audit found that in 95.4% of cases, there were no intraoperative complications. Posterior capsular rupture with or without vitreous loss occurred in 1.92% of cases. Some of the other intraoperative complications included simple zonular dialysis in 0.46%, retained lens fragments (dropped nuclei) in 0.18% and supra-choroidal haemorrhage in 0.07%. Other complications included post-operative uveitis (3.29%), raised intraocular pressure (IOP) (2.57%), cystoid macular oedema (1.62%) and iris prolapse (0.16%) which were noted 31 days (median) following surgery.[4] Posterior capsular opacification, bullous keratopathy, retinal detachment and endophthalmitis are other significant, sight threatening events that may be observed following cataract surgery.

Preoperative assessment

Refractive targeting

Cataract surgeons have become victims of their own success with regard to refractive targeting. Emmetropia had been an ancillary benefit of lens implantation during cataract surgery when lenses were first implanted. However with other frontiers crossed, the highlight has shifted towards a good unaided visual acuity post-operatively. Patients with high pre-existing ametropia in both eyes and bilateral cataracts should be counselled about post-operative anisometropia following first eye cataract surgery till the fellow eye cataract surgery is also done, should emmetropia be targeted following surgery. Otherwise, especially if there are asymmetrical cataracts, it would be a good idea to aim to reduce ametropia but only sufficient to balance the prescription to a level of anisometropia that could be tolerated.

Biometry

To accurately predict the optimum intraocular lens power to be implanted, formulae require the measurement of the axial length of the eye, corneal power and anterior chamber depth. When ultrasonic echo-impulse techniques are used for biometry, 54% of the error in the predicted refraction after implantation of IOL has been attributed to error in axial length measurement, 38% due to keratometric errors and the remaining 8% due to errors in estimation of post-operative anterior chamber depth (ACD).[5] Improving the accuracy of axial eye length determination has been postulated to have the greatest impact in improving IOL power prediction. This is because an axial eye length measurement error of 0.5mm for example, is capable of inducing a postoperative refractive error of up to 1.4D.[6]

Immersion ultrasound (wherein a transducer is suspended in a fluid coupling medium) is more accurate than applanation ultrasound.[7] However, ultrasound using A or B scan modality has been largely surpassed by partial coherence inferometry (PCI) using a semiconductor diode laser to determine axial length and ACD. This technique is non-contact, making it less skilled to perform consistently and is more comfortable for patients. PCI also ensures no indentation of the cornea preventing an underestimation of ACD and axial length. To obtain a good ultrasound echogram with sharp reflection peaks, the ultrasound beam must pass perpendicular to the segmental interfaces with the eye namely the cornea, the front and back lens surfaces and from the inner limiting membrane of the retina. The acoustical axial length approximates, but may not correspond exactly, to the visual axis. In contrast, PCI biometry relies on visual fixation to facilitate the measurement along the visual axis. Additionally, the dominant laser reflection originates from the retinal pigment epithelium, where the photoreceptors lie rather than the internal limiting membrane.[8]

Since the advent of the first commercial PCI device in 2001 (*IOLMaster*, Carl Zeiss Meditec, USA), this has become the technique of choice for cataract biometry due to its non-contact nature and its high resolution measurement of axial length (about ± 0.02 mm equivalent to 0.05D).[9] It has been shown to be accurate and reliable, [10, 11] improving the refractive results of cataract surgery.[12, 13] By 2004, the IOLMaster was being used in over a third of hospital eye units in the UK.[14] However, PCI fails to measure in up to 20% of eyes with dense opacities and macular disease, [11,15,16] although this can be reduced to less than 10% with more advanced analysis of the interference waveform.[9] Ultrasound is unable to measure in eyes filled with silicone oil, but PCI can.[15,17] Two new devices using Optical Low Coherence Reflectometry (OCLR), which is a similar technique to PCI (but with the laser replaced by a superluminescent light-emitting diode) have been developed namely *LenStar LS900* (Haag-Streit, Koeniz, Switzerland) and *Allegro Biograph* (Wavelight, Erlangen, Germany).

These devices have been shown to be as accurate and repeatable as the IOLMaster (Buckhurst at al., 2009 in submission), and gives the advantage of capturing all measurements without the need for realignment and the measurement of additional components of the anterior chamber (such as corneal thickness) for use in new and possible future biometry algorithms.

IOL power calculation formulae

Several generations of IOL power formulae have evolved, resulting in vastly improved the accuracy of post-operative refractive prediction. SRK-T, Holladay 1 & 2, Hoffer Q and Haigis formulae are commonly used. Although they differ little in predicted optimal IOL power in eyes with average axial lengths, some are more accurate than others for lengths outside the mean. The Royal College of Ophthalmologists, London have issued the following guidelines in the choice of formula[18]

Axial Length (mm)	Formulae
< 22	Hoffer Q or SRK/T
22 - 24.5	SRK/T, Holladay 1, Hoffer Q
> 24.6	SRK/T

The Haigis and Holladay 2 are newer formulae and hence have not featured in the above guidelines. The Haigis formula uses the anterior chamber depth (ACD) also and employs three constants. In one large series, it has been shown to be more accurate than Hoffer Q in extreme hyperopia.[19] It was also found to be the most accurate for long eyes (AL>25.0mm).[20] The constants in some formulae can be customised based on retrospective analysis of individual surgeon's post-operative results to increase their accuracy.[21] The Holladay 2 formula uses seven variables namely the axial length, lens thickness, corneal power (average K), horizontal white-to-white corneal diameter, ACD, pre-operative refraction and age of the patient. One study looking at the accuracy of IOL power prediction using the Hoffer Q, Holladay 1 and 2 and SRK/T formulae found no statistically significant difference between them for all subsets of axial lengths.[22] Individual surgeons continue to use their favourite formulae to give them IOL calculations but newer formulae should help to reduce residual refractive error, especially in the more extreme cases of biometric measures.

Post refractive surgery eyes

When patients who have had prior refractive surgery present for cataract surgery often many years later, accurate intraocular lens power estimation becomes challenging. When traditional keratometry and biometry methods are used on this subset of patients, there is a risk of inducing hyperopia following a prior myopic refractive correction or vice versa. Traditional IOL power calculation formulae are dependent on two variables, namely axial length and the dioptric power of the cornea. Based on these variables, the Effective Lens Position (ELP) that is, the eventual location of the IOL implant is calculated which subsequently yields the power of the IOL that is needed to achieve emmetropia. The location of the ELP is also based on the assumption that the anterior and posterior segments of the eye are proportional. A second assumption is in the determination of corneal diopteric power. It is estimated based on the central anterior curvature alone multiplied by the presumed average refractive index of the cornea, which is adjusted to account for the posterior corneal curvature which is roughly -10% of the power of the front surface. The resultant of these assumptions when applied to a situation where the cornea has been flattened centrally following myopic refractive correction by laser, leads to an estimation of the ELP to lie shallower than actual.[23] This results in an underestimation of the implant power resulting in a ‘hyperopic surprise’ in this situation.

Numerous formulae have been developed in an attempt to overcome this problem with varying success.[24] Preservation of pre-operative biometric data is vital in these patients as many formulae need those variables to calculate the IOL power. It is recommended that the following information should be retained by the patient undergoing refractive surgery: pre-operative keratometry and pachymetry, pre- and post-operative best corrected acuity and IOP and pre-operative and stabilised post-operative refraction. [25] Measurements of the true anterior and posterior elevation using the Scheimpflug principle and corneal thickness measurements may also be used in standard formulae reliably, without the need for any pre-refractive surgery data.[26]

Operative considerations

Anaesthesia

The UK EPR group have analysed data pertaining to anaesthetic techniques and complications in their dataset of 55, 567 operations. The audit found that local anaesthesia (which allows adequate anaesthesia for an approximately 30 minute routine cataract surgery in appropriate patient) was used in 95.5% of cases and the remainder were given general anaesthesia. The local anaesthetic methods varied from topical anaesthesia alone in 22.3%, topical and intracameral in 4.7%, subtenons in 46.9%, peribulbar in 19.5% and retrobulbar in 0.5%. One or more minor complications occurred in 4.3% of the local blocks administered by either sharp needle or subtenons cannula. Minor complications (such as chemosis or sub-conjunctival haemorrhage) were 2.3 times more common with subtenons blocks ($P<0.001$). Serious complications, defined as sight or life threatening occurred in 25 eyes (0.066%), undergoing sharp needle or subtenons cannula blocks. There was a 2.5-fold increased risk of serious complications with sharp needle techniques compared with subtenons cannula techniques ($P=0.026$).[27]

Astigmatic targeting

Pre-existing corneal astigmatism as identified by corneal topography can be surgically corrected at the time of cataract surgery. An "on-meridional" approach is where the incision is made on the steep axis of the corneal astigmatism with a view to reducing the diopteric power of that axis. However as the surgically induced astigmatism (SIA) of a standard corneal incision is low, combined with rapid wound stabilisation, the effect is small and unpredictable.[28] Opposite Clear Corneal Incisions involve making another self-sealing, stepped tunnel incision opposite to the on-axis primary surgical incision. Having two incisions along the steep axis enhances the effect of a single incision.[29] Temporal corneal tunnel combined with a paired Limbal Relaxing Incision (LRI) placed at the steep keratometric axis at the time of cataract surgery has been shown to have a more favourable and lasting effect.[30] Arcuate keratotomy has also delivered favourable results when performed at the time of cataract surgery.[31] Nomograms exist to get more predictable results using these interventions.[32] Individual surgeons use their preferred technique or a combination of techniques to optimise their results.

Toric IOLs

These lenses are of toroidal optical design intended to correct regular astigmatism at the time of cataract surgery. The effect of toric IOL implantation in reducing astigmatism is more effective and more predictable than any of the corneal surgical methods described above.[33, 34] The potential drawback of toric lenses is that the rotation of the implant away from the intended axis would result in a lesser correction. For example, if the lens rotates 30 degrees off axis, the astigmatic correction would be nil. Should the lens rotate more than 45 degrees off axis, the lens adds to the ocular cylinder, thereby making patients even more astigmatic than they were prior to surgery.[35] Surgical techniques to accurately position the toric lenses on axis and better IOL designs offering rotational stability are going to be the key determinants for the future success of this lens type. Modern loop and plate haptic toric IOLs have been shown to rarely rotate more than 15 degrees from the intended axis.[36]

Management of refractive surprises

In spite of best efforts, 'refractive surprises' do happen. This may be due to errors in biometry and the use of inappropriate power calculation formulae. Sometimes as a result of human error, a wrong lens can be implanted. In every case of unexpected refractive outcome, steps should be taken to review the process and identify the precise reason for this to have happened. Hospital critical incident procedures should be invoked for a multi-disciplinary approach with a view to learning from mistakes and minimising clinical risk in future.

The unexpected refractive error could be predominantly spherical, cylindrical or both. Unexpected astigmatism may result from poor wound construction (high surgically induced astigmatism), unplanned intraoperative conversion to a large incision to express lens fragments or due to the unmasking of high pre-existing corneal astigmatism that had been masked by lenticular compensation.

Surgical options for management of post surgery astigmatism include arcuate keratotomy if astigmatism is regular or laser refractive surgery. For spherical corrections, the surgical options include lens exchange, piggy-back lens implants or laser refractive surgery.

Advances in technology

Micro Incision Cataract Surgery (MICS)

Conventional phacoemulsification incisions are in the region of 2.8mm in length. This allows for the phacoemulsification hand-piece with a silicone sleeve covering it to fit snugly through the wound. The sleeve facilitates infusion around the needle and prevents thermal injury to the cornea. A second smaller incision is made to insert an instrument, the so called *second instrument* to manoeuvre the cataract during emulsification. The MICS concept involves removing the sleeve off the phaco hand-piece and transferring the irrigation system to the second instrument. This allows reducing the incision width to about 1.5mm.[37] Aggarwal et al from Chennai in India, have helped to rekindle the interest in this area and they coined the term Phakonit to describe their technique.[38] Microphacoemulsification is yet another term to describe the same concept although MICS has come to be accepted as the proper term for the procedure. Although this technique has been around for a while, the availability of lens implants that could be introduced through such small incisions has delayed its uptake. The benefits of MICS include a reduction in surgically induced corneal aberrations[39] and a potentially reduction in post-surgical infections. However it is not without its limitations. Dense cataracts have been difficult to manage owing to amount of heat generated. There is a loss of efficiency due to lower vacuum, aspiration and infusion rates. Incision leaks and loss of chamber stability have also been areas of concern. The phaco machines have stepped up to this challenge by enhancing the capability of the fluid management (infusion, aspiration and vacuum capabilities termed *fluidics)*; phacoemulsification energy delivery together with improved instrumentation to facilitate more effective MICS.[40]

Ultrasonic phacoemulsification is the standard for cataract surgery although laser has been tried but has never really caught on.[41, 42] Instead research is being focussed on refining existing ultrasound technology delivery in terms of instrumentation and energy delivery.

Hand-piece design and construction

The main developments in the hand-piece design and construction has been in the use of a flared tip to decrease ultrasound time and energy[43] and smaller frequency (sonic rather than ultrasound range) probes which are claimed to improve efficiency and minimisation of thermal dispersion.

Torsional and transversal ultrasound

Tip-fragment interaction is another area where major strides in phaco development are occurring. Conventional phaco tip movement is linear - like a jack-hammer effect where the stroke length determines the phaco power. Increased phaco energy results in greater corneal endothelial injury.[44] Torsional movements rather than the longitudinal movement are claimed to be beneficial for two reasons. First the linear movement in the conventional phaco tends to repulse the fragment away from the tip. Secondly there is no cutting during the backward cycle of the stroke. Both these drawbacks are overcome by the torsional movement.[45] Transversal ultrasound is another modification wherein the longitudinal movement of the phaco tip is combined with transverse movement giving rise to an elliptical motion.

Energy waveforms

The parameters involved in a phaco energy waveform are pulse width, frequency, energy and duty cycle. Continuous, pulsed and burst have been the traditional profile choices. Advanced power modulations include hyper-pulse and hyper-burst. While, traditional pulses or bursts are delivered in square waves, newer advances in software, permit gradual ramping up pulses and bursts (variable rise time) as well as delivering waveform-modulated packets of energy. The aim of these advancements is to minimise the phaco energy delivered and consequently minimising endothelial injury and heat damage to the wound.

Fluidics

Fluidics is based on the physical principles of fluid dynamics. In an intraocular environment, it concerns the co-ordination of vacuum, aspiration and flow. The suction force is generated by either a peristaltic or venturi pump in conventional systems depending on the machine type. Peristaltic pumps generate a vacuum on occlusion and it builds up steadily till the fragments are consumed when a post-occlusion surge is generated. A venturi pump generates a more constant vacuum and is capable of drawing fragments towards the tip. There are advantages and disadvantages with both systems and with conventional incision sizes, has been only a matter of surgeons' personal preference. However with MICS, a high degree of fine-tuning of the machines fluidics capabilities is required. The balance between inflow and outflow has to perfectly balance throughout surgery to maintain chamber stability.

A *dual pump* is an innovation that provides both venturi-type vacuum and peristaltic flow, controlled by specially designed software. It monitors vacuum levels, and when a pre-determined threshold is reached, backs up the pump instantaneously (response time as quick as 26 milliseconds) to reduce vacuum to a second, lower, pre-set level thereby reducing the post-occlusion surge. Other innovations include *non-compliant tubing* to help suppress surge; enhancement of outflow stability by a *micromesh filter* that prevents particles from clogging the aspiration line, allowing vacuum and flow to be maintained at a constant and a *bypass valve* that opens during surges to pull fluid from the bottle instead of the anterior chamber thereby preventing sudden IOP drops.

In addition, advanced software and sensors also contribute to surge suppression and fluidics control.

Ophthalmic Viscosurgical Devices (OVD)

Viscoelastic substances play a major role during surgery. Advances in this field have pushed the safety margin further. The shearing force generated by ultrasonic phacoemulsification, fluids and lens fragments tends to damage the endothelial lining of the cornea. Viscoelastic substances when injected intracamerally, protect the endothelium by lining it (visco-dispersion). They also create space (visco-cohesion) to work safely with instruments. Higher density polymers have uses if greater cohesive power is demanded during surgery. Viscoelastics that are either predominantly dispersive or cohesive are available or in combination to be used concurrently.[46] Newer agents are capable of transforming from dispersive to cohesive depending on the shear rate (visco-adaptation).[47] A lesser known benefit of OVDs is their role in inhibiting free-radicals generated during phacoemulsification.[48] Higher viscosity agents are difficult to remove completely at the end of surgery and incomplete removal leads to increased IOP in the early post-operative period.[49]

Advances in intraocular lenses

Aspheric lenses

The cornea has a positive spherical aberration which increases with age. This is countered by the negative spherical aberration of the crystalline lens. When the cataract is removed this effect is lost and further positive spherical aberrations induced when an IOL of convex spherical design is implanted. Spherical aberration results in lowered contrast sensitivity. Aspheric lenses are designed with a more prolate edge to reduce the spherical aberration. Good centration of these lenses is the key to achieving maximum reduction in aberrations.[50]

While no difference in visual acuity was found in comparison to spherical lenses, the results of aspheric lenses with regards to improvements in contrast sensitivity have been mixed. No significant difference in contrast sensitivity between spherical and aspherical lenses at three to four month follow-up was found in one study[51] However other studies have reported significant improvement in contrast sensitivity[52,53] and without a reduction in pseudoaccommodation amplitude[54]. A reduction in the depth of focus which can result from asphericity is an important consideration as most patients undergoing cataract surgery are presbyopic.[55] In a postal survey of ophthalmologists in New Zealand done in 2007, 27% of surgeons who responded claimed to use aspheric IOLs routinely.[56]

IOLs for presbyopia

IOLs for presbyopia are of two types namely the multifocal pseudoaccommodative and the 'true' accommodative designs. Early generation IOLs for presbyopia (refractive multifocal) were designed to have different refractive zones arranged concentrically, alternating between distance and near focal lengths (pseudoaccommodation). Newer designs have altered the zone width and introduced intermediate focal length zones, in addition to aspheric surfaces which enhance the spherical aberrations of the eye and hence depth of focus.[57]

IOLs have taken advantage of diffractive optics.[58] Whereas a smooth convex surface of a lens produces one sharp point of focus for the image, diffractive lenses by way of a stepped design on the lens surface diffract the light resulting in two focal points. The central zone of the lens is apodised whereby the diffractive step heights are gradually reduced and blended away towards the periphery. At smaller pupil diameters the light energy is directed towards the near focus and at larger pupil sizes, towards the distance. Good lighting during near tasks enhances this effect. Some comparative studies have found that diffractive lenses perform better than refractive multifocal lenses and have lesser photic effects. [59, 60, 61]

'Accommodative' IOLs try to mimic the crystalline lens, changing position or curvature in response to contraction of the ciliary muscle contraction. They are designed to work on the optic shift principle, with the IOL moving forward on attempted near focus due to increased lens capsule equatorial tension on the flexible 'hinge' haptics. The consensus of long-term follow up studies which assess ocular accommodation both subjectively and objectively are that the restoration of eye focus is limited and reduces with time, perhaps due to fibrosis around the haptics.[62]

One of the major issues with developing IOLs that can mimic the crystalline lens is in 'coupling' them with the ciliary muscle via the zonules and lens capsule. The size of the capsular bag varies between individuals and cannot currently be measured pre-operatively by clinically available techniques. A lens that is too large for the capsular bag will absorb some of its mechanical focusing ability without any attempted near focus, and will result in a change from the intended refractive distance power. Those IOLs that are too small for the capsular bag are unlikely to couple well with the ciliary muscle action, resulting in a reduced eye focusing effect. Despite significant advances in ocular imaging, imaging the periphery of the crystalline lens behind the pupil is still a significant challenge.[63]

All presbyopic lenses have their individual strengths and weaknesses due to their optical design and mechanism of action. A 'mix and match' philosophy involves using a lens of a different type for each eye has become popular to overcome the individual limitations of different presbyopic IOL types. The initial results of this approach are encouraging.[64,65]

UV absorption

The crystalline lens absorbs most of the incident UV radiation wavelength region of 300- 400 nm. This protects the retina from photochemical damage. However, when the lens is removed during cataract surgery, this protective effect is lost thereby increasing the risk of progression of age-related macular degeneration (AMD).[66] The other benefits of UV blocking lenses include restoration of normal spectral sensitivity, reduction of erythropsia and cystoid macular oedema and stabilisation the blood-vitreous barrier.[67] IOLs are being manufactured with UV-absorbing chromophores incorporated into the lens material as well as blue and violet blocking filters. At the same time it would not be appropriate to replace a naturally yellowish (nuclear sclerotic) for another albeit artificial one. Therefore degree of chromophores density in an IOL should be able to achieve the balance between photoprotection and photoreception.[68] To address this issue, a photochromic IOL that is clear but becomes yellow when exposed to UV light, has now become available.[69] Other blue blocking and violet blocking lenses have been available for a while, although controversy still presides over whether the potential benefits of reduced oxidative stress to the retina outweigh the effects of potential light reduction and disruption of circadian rhythm.[70]

Posterior capsular opacification

Posterior capsular opacification (PCO) is due to the proliferation, migration and myofibroblastic transformation of lens epithelial cells on the posterior capsule behind the IOL.[71] It ranks as the number one complication following cataract surgery. Whereas originally the lens biomaterial was thought to be a major determinant, it is now largely recognised that the design of the IOL, principally a square edge of the optic, acts as a barrier to the migration of these cells.[72] Enhanced square edge designs are now available providing a raised edge and consequently a greater barrier function. PCO or 'after cataract' as it is sometimes known, should it happen, can be easily and effectively treated by posterior capsulotomy with Nd:YAG laser. Retinal detachment is no longer considered a risk following Nd:YAG laser capsulotomy after phacoemulsification cataract surgery.[73] However, the optical properties of the newer lenses risk being seriously degraded following capsular opacification and its removal. Posterior optic buttonholing is a technique whereby a 4mm or smaller opening is made in the posterior capsule and the optic is prolapsed into the opening. This technique was adopted from paediatric cataract surgery where the PCO rate following cataract surgery is extremely high. In a consecutive series of 1000 patients, this technique has been shown to be safe and effective.[74]

Future developments

Three lens designs being evaluated as accommodative lens implants are showing promise. Dual optic lenses consist of a mobile front optic and a stationary rear optic which are connected by spring-type haptics. Magnet-driven systems are claimed to provide an active-shift lens, in contrast to the passive-shift lens that is currently available. Here the moving force is provided by repulsing mini-magnets. Lens refilling is yet another method where the lens content is replaced by an elastic material and provides accommodation by an increase of surface curvature.[75]

Sealed-capsule irrigation system is a device that has been developed to selectively deliver an agent to target lens epithelial cells following cataract removal.[76] The agents/mechanisms currently investigated to prevent PCO include nuclear factor kappaB (NF-kappaB),[77] proteasome inhibition,[78] macrophage depletion[79] as well as drugs like ciclosporin A[80] and mitomycin-C.[81]

Moving away from the surgical options, drugs have been tried as a therapeutic option for cataracts. N-acetyl carnosine is one of the topical agents that has been developed for this purpose. The Royal

College of Ophthalmologists is very sceptical about its claims of cataract reversal and has warned against its use until more robust scientific data to back its claim becomes available.[82] Agents like epigallocatechin gallate are being evaluated to protect the lens from UV damage which might slow the rate of cataract progression.[83]

Conclusion

Cataract is the most commonly performed ophthalmic procedure in Australia and the numbers are expected to double in the next half-century.[84] This paper has highlighted some of the latest innovations in cataract surgery and intraocular lenses. We envisage that future advances in intraocular lenses will allow the restoration of clear vision and eye focus, combined with protection of the retina from harmful radiation. Consideration in the future may be whether crystalline lens replacement should occur when presbyopia sets in, rather than waiting until cataracts have formed at which point other health complications may affect surgery.

Cataract is one of the major causes of preventable blindness in the developing nations. Cutting edge technology comes with a price which developing nations struggle to adopt. Challenges, such as the management of posterior capsular opacification can be more expensive than the surgery itself in such settings. However surgeons in those parts of the world have good surgical skills which they have used to develop techniques for small-incisional cataract extraction that can deliver results comparable with phacoemulsification. Collaborative research, including partnership between academia and industry is the way forward to ensure scientific rigour and cost-effectiveness so that the fruits of science are available for all of humanity to devour.

The described innovations will increase the role of optometrists in advising patients of the options and risks and managing their expectations. They are best placed to assist patients on when it is best to have surgery in consideration of quality of life and co-morbidity related issues. Optometrists are also critical in the monitoring of post-surgical complications and their management; identification and correction of residual refractive errors and in the decision making process regarding second eye surgery. Crucially they play an integral part of the continual clinical audit framework that is necessary to maintain high standards of care.[85]

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