Improving the Refractive Outcome of Cataract Surgery

by Dr Graham Barrett, Australia

It is a great honor to have been selected to present the Asia-Pacific Intraocular Implant Association (LIM) Lecture at this the 8th ICIMRK meeting in Bali, Indonesia.

The Asia Pacific region is the most rapidly developing region globally today. These dynamic changes are not only economic, but are also reflected in the changes in health care, and health delivery, that have occurred in the last decade. The region poses special challenges in that there is a wide divergence in the level of sophistication, and technology, in different countries, which constitute the Asia Pacific region.

The Asia-Pacific Intraocular Implant Association is a body dedicated to the field of cataract surgery and intraocular lens implants which probably has the most potential to restore vision to people in this region. No one person has had a greater personal impact in ophthalmology than the current president of the APIIA, Professor Arthur Lim. It is therefore a special honor to be delivering a lecture named after this unique individual.

The contribution of Arthur Lim to ophthalmology is vast, including extensive clinical and teaching appointments, and includes the publication of many papers and books, as well as serving on the editorial board, and being editor-in-chief of several journals. His influence in ophthalmology is not confined to the Asia Pacific region, but is indeed felt globally where he participates at the highest level. Professor Lim has many international appointments, and has organized major international meetings and courses.

I have been fortunate enough to have participated in some of these meetings including the 2nd, 3rd and 4th ICIMRK meetings where I have had the opportunity to meet Professor Arthur Lim personally, and am fortunate in being able to consider him not only as a colleague, and teacher, but also as a friend. In this capacity I have been especially impressed by his capacity not only to consider and contribute to the high tech aspects of modern cataract surgery, but also to balance this with an understanding of the need to deliver cost effective cataract and implant surgery in areas where this is not yet available.

Today I would like to consider factors, which can improve the refractive outcome of cataract surgery. The most important contribution in this area was the introduction of intraocular lens implantation by Harold Ridley in 1949. This event heralded a new era, but the postoperative refraction in the initial patient was -18 dioptres of myopia with an associated 6 dioptres of astigmatism. There was therefore considerable room for improving the refractive outcome, and this has been a special interest of mine as an ophthalmic surgeon and I would also like to outline some of my personal efforts and thoughts on this endeavor.

Modern cataract surgery should be safe, painless, with a rapid recovery of vision. Patient's expectations include good unaided acuity, as well as corrected acuity. Unaided acuity is dependent on the residual refractive error, which has two components, the spherical and astigmatic refractive outcome.

(A) Spherical Refractive Outcome:

Initially I would like to consider the three factors that is surgery, prediction, and monitoring, which influence the spherical equivalent refractive outcome.

Surgery: The implantation of an intraocular lens has a dramatic influence on refraction and can be effected by decentration, tilt, and axial location of the implant. Surgery can influence these factors by ensuring symmetrical capsular bag placement of an intraocular lens. This is best accomplished by capsulorhexis which has been a major refinement in modern cataract surgery.

Prediction: The second factor, which influence spherical equivalent refractive outcome, is being able to predict the correct lens power to achieve a desired refraction.

If one analyses the causes for errors in prediction of lens power, incorrect estimation of the axial length, anterior chamber depth, and astigmatism explain the majority of cases, but in almost a quarter of cases the reason for an incorrect lens power remains unexplained. At least some of these cases the incorrect IOL power prediction is related to the formulae which are utilized to predict lens power. There are many formulae, which have been developed to improve the prediction of lens power, and these can be grouped into theoretical or statistical formulae. The formulae tend to concur for the mid range of axial lengths, but diverge, and *are* both deficient for eyes with short and long axial lengths. This led to the development of a third generation formulae such as a Holladay, and SRKT formulae, which use different strategies to locate the iris ciliary plane which determines anterior chamber depth.

I have also developed a new formula termed the "Universal Formula" which is based on the concept of a new model eye. The Universal Theoretical Formula considers the model eye as the intersection of two spheres, an anterior corneal sphere with a posterior global sphere. This intersection defines a ciliary diameter at the iris root, which divides the anterior chamber depth into anatomical and IOL related components. I have evaluated this formula and compared it to the SRK, SRKII, SRKT, and Holladay formulae, looking at the mean absolute error, and percentage of cases within a defined refractive error as an indication of the accuracy.

I evaluated the formulae in four groups of patients. Group A consisted of 100 unselected eyes, Group B consisted of 25 eyes with short axial lengths less than 22.5mm, Group C consisted of 25 long eyes with axial lengths more than 24.5mm, and Group D consisted of 50 average eyes with axial lengths between 22.5m and 24.5mm.

The Universal Formula had the lowest mean absolute error in all four groups, as well as the highest percentage of cases within 1 dioptre in all four groups compared to the other formulae. The results indicated therefore that the concept of the model eye was valid, and the formula could be considered universal, not only for different intraocular lenses, but also for eyes with varying axial lengths.

In order to be able to predict an intraocular lens power accurately, accurate measurements of keratometry and axial length are vital. These measurements should be repeated if unusual, and finally a third generation formula such as the Universal Formula should be utilized.

Monitoring: The third factor, which should be considered in improving spherical equivalent refractive outcome, is to monitor the pre-operative keratometry and axial length as well as the postoperative refraction. This allows one to optimize a personal A Constant, which further refines the ability to predict the correct lens power for an individual patient. I have developed computer software, which facilitates this process.

(B) Astigmatic Refractive Outcome:

I would now like to consider the astigmatic refractive outcome and the three factors, surgery, prediction, and monitoring, which influence this component of the final refractive outcome. The most important aspect of surgery, which influences the astigmatic outcome, is the incision. Various factors influence the induced astigmatism but the most important factor is size, and a small incision does produce less astigmatism, and a stable refraction with early visual rehabilitation.

Surgery: The introduction of phacoemulsif cation enables the surgeon to remove a cataract through a 2.5mm to 3.2mm incision. Phaco requires a considerable investment not only in equipment, but more important in training and experience to perform phacoemulsif ication safely and effectively. It is important to understand details of the surgical technique and the various components such as ultrasonic energy, pumps, and infusion, which make the operation feasible. Phaco dynamics refers to the interaction of vacuum infusion, and wound leakage, which can be summarized by a simple equation that fluid inflow should equal fluid outflow for chamber stability.

Although phacoemulsif ication can be accomplished through a 2.5 to 3.2mm incision PMMA intraocular lenses require a 5.5 to 6mm incision for insertion. To obtain the full benefit of small incision surgery therefore, one requires flexible intraocular lenses. Flexible lenses can be described as first generation lenses, such as the original IOGEL lens, which had plate haptics, secondary generation lenses which are flexible lenses with conventional styling, either three piece or one piece in design, and finally third generation lenses with so-called hybrid haptics which have elements of both previous designs.

I have designed a hydrogel implant termed "the 2000 series" where the design aim was to combine the ease of insertion of a plate haptic with the improved fixation typical of a conventional loop haptic design. The lens has a 5.5mm or 6mm optic, which merges via a crescentric flange to a terminal loop. The haptics are considerably more flexible than conventional three piece or one piece lenses, and the design concept is based on one of minimum haptic rigidity.

I believe with modern techniques such as capsulorhexis, a haptic has adequate rigidity if it is able to support the lens in the capsular bag. I first implanted this lens in October 1991, and in September 1992 established an international study group. This group consisted of ten investigators and 200 patients have had the lens implanted with a follow up of up to twenty-four months.

The study results show that the lens is well tolerated, provides excellent acuity, and good centration. Most important the new design has improved fixation and stability, compared to previous plate haptic hydrogel lenses.

Prediction: The second factor to consider in improving the astigmatic outcome of cataract surgery, is being able to predict the induced astigmatism produced by a particular incision. The factors, which need to be considered, include the pre and postop keratometry as well as the incision, size, location, and whether sutures were utilized.

In 1987 I compared the induced astigmatism and unaided visual acuity in three groups of patients. This demonstrated that a 3.5mm incision with phaco and a foldable lens had a significantly higher percentage of patients achieving 6/12 or better unaided acuity compared to a 6.5mm incision, phacoemulsification, and 10mm incision, a manual extracapsular cataract extraction. This study demonstrates that a small incision is superior, but in 1995 we need to know whether a 3.5mm incision is best performed in the sclera, or the cornea, and whether this should be located vertically, or temporally.

I have performed such a comparison, which indicates that at one week the scleral incision with an X suture has a small amount of with the rule astigmatism, which is reduced by eight weeks. The same unsutured incision produces a small amount of against the rule astigmatism which increases slightly at eight weeks. In contrast a clear corneal vertical incision has a significant amount of against the rule astigmatism induced at one week which diminishes by eight weeks. A clear corneal incision performed temporally, however, produces a small amount of with the rule astigmatism at one week, which declines to a negligible level at eight weeks. Because the vast majority of patients have pre-existing against the rule astigmatism a clear corneal temporal incision tends to have the most favorable astigmatic result, and also has other advantages such as lack of bleeding, and less trauma as indicated by this patient less than one week postop.

Monitoring: Finally I would like to consider the monitoring of induced astigmatism at the time of surgery as another possible way to reduce astigmatism and improve the refractive outcome of cataract surgery. Existing quantitative keratometers are expensive and require adjustment which is often time consuming, whereas qualitative keratometers tend to be reflective with a poor image and tend to be inaccurate. I have developed a qualitative keratoscope, which is a keratoscopic lens that focuses a microscope light and therefore produces a brilliant image. I have now developed a quantitative version of this lens which produces three ring images of the microscope light. The keratoscope also has an inbuilt scale on the handle to facilitate interpretation of astigmatism. To use the keratoscope the surgeon simply observes the reflective image and estimates the relative ellipticity of the 3 ring images. If the central image is most circular then this equates to 0 dioptres. If the middle image is most circular this is equivalent to 2 dioptres of astigmatism. Finally if the outer image is most circular then this is equivalent to 4 dioptres of astigmatism. If the inner and middle ring appear identical then this equates to 1 dioptre, and if the middle and outer image appear identical this is equivalent to 3 dioptres of astigmatism.

In order to estimate the accuracy of the keratoscope I initially compared the estimation of astigmatism on the slit lamp in 50 consecutive cases with a B&L keratometer and looked at the mean absolute difference. I also estimated the induced astigmatism at the time of surgery in a series of patients, and compared this to the astigmatism measured by keratometry on day five postop. I performed this in twenty-five consecutive cases with a quantitative keratoscope another, twenty-five consecutive cases with a qualitative keratoscope to provide a comparison. The correlation coefficient between the quantitative keratoscope and the keratometer on the slit lamp was 0.9 with a mean difference of .09. The mean absolute error for astigmatism estimated at the time of surgery compared to that measured at five days postop was significantly lower with the quantitative keratoscope than the qualitative keratoscope. The results indicate that the keratoscope provides an accurate estimation of astigmatism, and should be a useful device for surgeons to monitor and adjust induced astigmatism at the time of surgery.

This completes my presentation on how the spherical equivalent and the astigmatic refractive outcome can be influenced by surgery, prediction, and monitoring, and my personal endeavors in this area to try and improve the refractive outcome of cataract surgery.

Finally I would like once again to express my thanks for the honor of delivering this lecture, and also congratulate Professor Ilyas and the other organizers for organizing a successful 8th ICIMRK meeting in Bali.
8th ICIMRK Meeting, Bali, Indonesia, 1995.