

REMEMBRANCES OF THINGS PAST

BARRIE JAY, EDITOR

Harold Ridley and the Invention of the Intraocular Lens

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Abstract. On November 29, 1949, Harold Ridley implanted the first intraocular lens (IOL). This marked the beginning of a major change in the practice of ophthalmology and, for Ridley, the beginning of an era of inspiration, reward and challenge, unfortunately marred by the disdain and discourteous actions of many colleagues within the academic establishment in Europe and the United States. By the late 1970s IOLs and implantation procedure had undergone many improvements, and Ridley's invention had become an accepted option for the optical correction of aphakia. Since that time Ridley has been accorded the recognition due to him for his unique contribution to ophthalmology through the conferring of numerous awards and honors. This colorful biographical account is based on published history, statements from Ridley's colleagues, and recent interviews with Ridley himself. (*Surv Ophthalmol* 40:279-292, 1996)

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On November 29, 1949, Harold Ridley implanted the first intraocular lens (IOL). In so doing he changed the practice of ophthalmology. Not only will Ridley's invention provide superior visual rehabilitation to cataract patients for generations to come, but also, without his having realized it, the IOL has been a major factor in changing the way ophthalmology is practiced. The fact that lens implantation is by far the most common and one of the most successful of all eye operations has virtually created a medical-industrial complex. In business terms, the IOL procedure – and its cousin, refractive surgery – have become "products" that can be marketed and sold to a wide base of consumers. In the United States, the economic fallout of these procedures has already changed ophthalmic practice patterns and has helped accelerate the pace towards managed care.

This article commemorates the 45th anniversary of Ridley's first implantation. In addition, we celebrate the conferring of the Gonin Medal on Ridley, one of the highest honors bestowed upon an ophthalmologist. It was presented to him in May of 1994 in Lausanne, Switzerland, and reaffirmed in July of 1994 at the quadrennial meeting of the International Congress of

Ophthalmology, Toronto, Canada.

Harold Ridley (Fig. 1) wishes to be remembered for "completing the cure of cataract by the implantation of an artificial lenticulus." His invention of the intraocular lens has had a major impact on the specialty of ophthalmology, both in terms of how it is practiced and of benefit to patients. We provide this biography as a token of gratitude to Mr. Ridley on behalf of all individuals who have benefited from his discovery. The contents of this work are based on a review of the literature, on comments of many of Ridley's colleagues and contemporaries, and on numerous personal conversations between Ridley and one of us (DJA) over the past decade.

Chronology

CHILDHOOD AND EDUCATION, 1906-1938

Nicholas Harold Lloyd Ridley, M.A., M.D., Cantab. (Cambridge); F.R.C.S., England; D.H.L. Medical University of South Carolina, Charleston; D.S. City University of London; Fellow of the Royal Society, recipient of the Gullstrand and Gonin Medals, was



Fig 1. Harold Ridley, circa 1950, at the time of the first IOL implantations.

born at Kibworth, Leicestershire, July 10, 1906. His mother was Margaret Parker, a member of a prominent yeoman family in Cheshire. His father, Nicholas Charles Ridley, M.B., F.R.C.S., R.N., was consultant ophthalmic surgeon to the Leicester Royal Infirmary. Harold's only sibling was a brother Alder, who was three years younger. The Ridley name extends back many centuries. In 1555 one of Ridley's ancestors, also named Nicholas, Bishop of London and Master of Pembroke College, Cambridge, was martyred at Oxford, a victim of religious persecution.

Harold's father had been commissioned in the Royal Navy. In 1889, while serving in the China Station, he developed severe joint hemorrhages which were found to be the result of hemophilia. He was discharged from the navy for health reasons in 1892. After discharge his disability proved too severe for his planned career in general surgery. He therefore turned to ophthalmology, which was less arduous. He held several posts at the Royal London Ophthalmic Hospital (Moorfields) before receiving a hospital appointment in Leicester in 1896. A hemophilia-induced arthritis that ensued was so crippling that for many years he was compelled to perform his work, including eye surgery, using crutches – often in considerable pain. Despite his health problems, Nicholas Ridley lived and successfully practiced ophthalmology in Oadby, a village near Leicester, for many years. He died at home of cerebral hemorrhage in 1937.

His son, Nicholas Harold Lloyd Ridley (hereafter termed "Ridley"), spent his childhood in Oadby. He attended Charterhouse, a prominent boarding school in Godalming, Surrey, from 1920-1924. From 1924 until 1927 he attended Pembroke College, Cambridge, with emphasis on Natural Sciences. (This was the equivalent of undergraduate premedical training in the USA.) After successfully completing the Tripos [honors degree earned following a qualifying examination] at Cambridge in 1927, Ridley proceeded with medical training at St. Thomas' Hospital, London* and in 1930 completed his basic medical education. He received an M.D. Cantab (Cambridge). He spent six months as a casualty officer at St. Thomas' and in 1931 completed a year of general surgery at St. Thomas'. He then worked in the eye department for six months under Mr. A. Cyril Hudson. In July of 1932, at age 25 (the youngest eligible age), he received the FRCS (Fellow Royal College of Surgeons). He was influenced by his father to enter ophthalmology; His first exposure to organized ophthalmology was in 1930 when he attended the Oxford Ophthalmological Congress as a guest of his father. However, the time he spent with Mn Hudson (Huddy) in ophthalmology at St. Thomas' was also very important to Ridley. Ridley had done 140 nonophthalmologic operations in the main theaters (operating rooms) during his year of general surgery and had passed the F.R.C.S. However, it was the custom that house surgeons did not do eye surgery during the very early phases of training and Ridley did not do eye operations during this period. However, vast surgical experience came later and he always regarded Huddy as his finest teacher. Says Ridley, "He certainly taught me how to do extracapsular extractions and he was far better than anyone at Moorfields." The second surgeon who was highly influential to Ridley at that time in the St. Thomas' Hospital Eye Department was Geoffrey Doyne. Doyne's father,

Robert, was the discoverer of Doyne's honeycomb retinal dystrophy and the founder of the Oxford Congress. Doyne, with appointments at both St. Thomas' and Moorfields Hospitals, helped ensure that Ridley was fully trained by recommending that he do further training as a registrar at Moorfields. Ridley was, thus, from the beginning, exposed to the best of the eye surgeons in London, learning something from each of

* As a gesture of appreciation to St. Thomas' Hospital for his early medical training and as the site of his first IOL implantation in 1949, Ridley later established a foundation that bears his name. The Ridley Foundation was established on March 29, 1967, to relieve poverty amongst the hospital staff, to reduce blindness amongst the underprivileged and to promote research in ophthalmology at St. Thomas'. Though the legal document dates from 1967, the idea began in the 1930s when Ridley was an ophthalmic registrar (resident),

them. Doyne took Ridley in hand and became almost a second father, giving wise advice and every encouragement. Ridley acknowledges Doyne's role:

I am very conscious of the great debt I owe to this man who could surely not have had an enemy in the world. My career would have been very different without him and his wise guidance. He was a good ophthalmologist, worthy of his place on the Moorfields staff. Though he did not live to see our work fully accepted I sincerely hope that he derived some pleasure from supporting me in the early stages. How kind God was to give me two such wonderful teachers. Of the two, Huddy was the finest teacher, but I really believe that Geoffrey Doyne gave me the greater help and guidance.

Soon after his qualification and prior to beginning his ophthalmology training at Moorfields, Ridley bided his time as temporary House Surgeon and anaesthetist at Derby Royal Infirmary. In addition, recalling that "my father had wanted me to see the world before I became too busy," he found various positions as a ship's surgeon in 1933-34. He served for several months as ship's surgeon in the Baltic. He also served on a four-month voyage to Japan again reliving an experience of his father, who had worked as a ship's surgeon in Japan in 1884-85. Following these adventures he was very keen to find useful work again and, fortunately, as recommended by Doyne, he was offered an 18-month period of ophthalmology residency training at Moorfields in 1934-35. There, Ridley observed:

In the early thirties hospital conditions were little better than a century before, except that local and general anaesthesia had become available. There was only one operating theater and that was equipped with a wooden operating table, a masterpiece of carpentry. To readers of this report the theater must seem unbelievable but sepsis was uncommon except after orbital trauma. The striking discovery for me was that operative technique was really poor and far below the standard of Huddy at St. Thomas' Hospital. This was because World War I had deprived aspiring surgeons of their proper training. A generation of ophthalmologists, German as well as Allied, had been lost in the war. The next generation therefore was not properly taught. Some men indeed had actually been promoted to staff level when still house surgeons.

Believe it or not, when I became a Moorfields resident, only two out of twelve full surgeons had ever been 'through the house'. Huddy, had he still been at Moorfields, would have been a third. There was 1, the first of a new generation of ophthalmic surgeons given, by God, The chance to pick out the best features from the work of each of my superiors and develop technique up to the standard of the day. I was given much more surgery than any of my predecessors and passed up some suggestions to my seniors.

Ridley performed 109 cataract extractions during 12 months of active time in the operating room. In those days the average number of cases performed by a young resident was 30 to 40. His first techniques for cataract surgery were influenced by the Viennese

School of Ophthalmology. He visited Vienna, Budapest and Munich for about four weeks after the completion of training in 1935. He was very impressed by the "general excellence of ophthalmology throughout continental Europe." At that time the preferred single technique was intracapsular cataract extraction (ICCE). However, even though Ridley was not permitted to perform the technique of extracapsular cataract extraction (ECCE) until later when he became a consultant, he recognized at this early stage that the ECCE technique was generally safer and preferable to ICCE.

Most fortuitously, ECCE turned out to be the technique most amenable to implantation of Ridley's subsequent invention, the intraocular lens (IOL).

in 1938 Ridley was appointed full surgeon and permanent consultant at Moorfields Eye Hospital.

in my second year as resident my seniors sometimes called me in as a second opinion in Harley or Wimpole Street. Three surgeons made me run their practices during their absence on summer holiday. Inevitably this good fortune brought forth jealousy among my contemporaries but the staff supported me and made a special vacancy for me to be Registrar. When staff vacancies arose the following year I was appointed full surgeon at the very early age of 32 years and 9 days, with all votes save one (the aunt of a rival). Obviously something had to be done to put the hospital back to where it used to be before World War I – to restore it to be once more the ophthalmic center of excellence. I spoke to the chairman of the governors, Mr. Luling, and he immediately promised money to pay the costs of more junior staff if the medical committee so recommended. There was to be a proper training program based on teaching good young men and not simply exploiting them to see far too many patients each day. The idea of a Dean and medical school immediately caught on and the duration of a resident's job was increased from 1 years to 2 years, and soon after to 3. Teaching, however, was still to be done entirely by clinicians who were always overburdened with patients who had to be seen. Some of them charged fees to earn the surgeon's meager living. I believe that the refounding of Moorfields as a teaching center was the very best thing that I ever did for British ophthalmology until implants eventually arrived. Within a few years World War II began and little could be done until peace returned.

WORLD WAR II, 1939-1945

World war II began in 1939, shortly following Ridley's appointment as permanent consultant at Moorfields, and he fully expected an immediate entrance into the Royal Army Medical Corps. However, the "phony" war (prior to the time of active hostilities) began and there was almost no military action except for a few isolated attacks by sea or in the air. Physicians in military hospitals had very little work, but Ridley remained throughout the winter working at St. Thomas' and Moorfields Hospitals, and at the Royal



Fig 2. Harold Ridley, Major, Royal Army, Ghana, circa 1941. Ridley (right) is in the village of Fulnsi, performing investigations on onchocerciasis (river blindness).

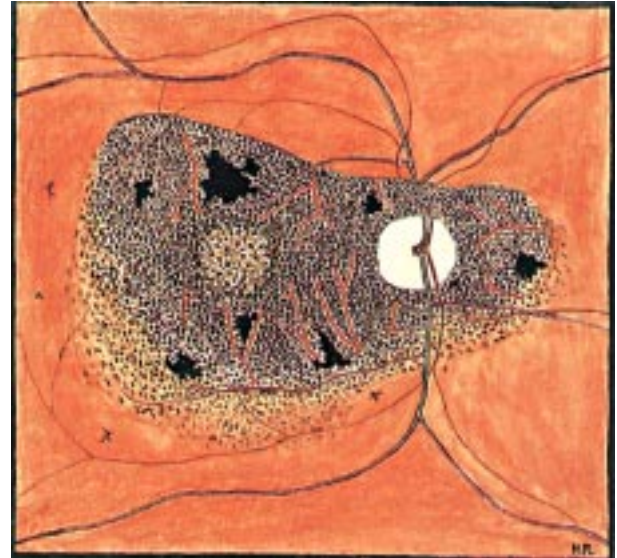


Fig 3. Fundus drawing painted by Harold Ridley showing severe pigmentary changes that occur at the posterior pole in onchocerciasis.

Buckinghamshire Hospital in Aylesbury. From 1939 until early 1941 he also served in the Emergency Medical Service in Guilford, where he saw numerous casualties. In the "phony" or "twilight" war, Ridley was much more active and useful as a civilian physician in the Emergency Medical Service than were many physicians on active duty in the army.

In Surrey, on May 10, 1941, Ridley married Elizabeth Wetherill, who was "by training a school teacher. She was a Red Cross nurse during wartime. However, ultimately for me she was a secretary, diarist, and general helper in many ways – not at all medical, but an essential part of the team." They had three children, Margaret (born 1942), Nicholas (born 1943) and David (born 1951). Also in May of 1941 Ridley was appointed temporary Major, Royal Army Medical Corps. In that year he was sent to Ghana in the Gold Coast of West Africa by Sir Stewart Duke-Elder, then the ranking ophthalmic officer in the British Army. Says Ridley, "This distressed me, for West Africa was not likely to be a fighting area where surgical experience would be of value." However, this assignment turned out to be a blessing in disguise; it was the period when he performed his original work in the field of tropical eye disease, especially onchocerciasis. After 18 months in Ghana, Ridley went to Aldershot Army base near Guildford and was then ordered to fly to Poona, India, then by train to Calcutta. He recalls,

In Calcutta we basically had nothing to do, with no assignments—a situation which continued after transfer to Parragan near Calcutta. Finally, I was transferred to Rangoon, Burma, where life began again. I treated over

200 released allied prisoners of war in Rangoon and Singapore who suffered from nutritional amblyopia while Japanese prisoners of war. Many of the prisoners had worked on the Burma Railway. Starved and ill-treated, they had developed sudden central scotoma, relieved by good diet if available. Some developed optic atrophy, some of whom made a partial recovery within six weeks of release. However, the advanced cases, though given a vitamin-rich diet were irreversible I subsequently wrote an article on the topic of nutritional amblyopia.

Ridley later described his work with former POWs as the most rewarding and "happiest days" of his war service. Ridley also recalled how Chinese residents, joyously welcoming the return of the British Army after the recapture of Singapore, had provided the soldiers with alcohol—unfortunately methyl alcohol. About 20 deaths and many optic catastrophes resulted.

POST-WAR, 1945 PRESENT

Having been scheduled for discharge in 1946, Ridley received an early release from the Army in 1945 with the rank of major. This early departure was ordered to enable him to return to London to utilize his tropical medicine experience to treat returning prisoners and refugees who suffered blindness from vitamin A deficiency. He continued his interest in this field. He served as Post-war Consultant in Ophthalmology, Ministry of Defense (Army), until 1971. From 1965 to 1971, he was a member of the Expert Advisory Panel 011 Parasitic Diseases (filariasis) for the World Health Organization (WHO).

With Mrs. Ridley and one of the ophthalmic sisters (nurses) we would all work very hard, and all received National Health Service pay, but no private fees. Registrars

(residents) were sent to follow up the work, the most notable Cobb Awdry to Rhodesia where they confirmed the need for early treatment of vitamin A deficiency in infants. It was said that the incidence of vitamin A-related blindness in children went down by 90%.

Ridley was appointed Honorary Ophthalmologist, Ministry of Defense (Army), confirming the value of his service. He resumed duties as consultant, with affiliation at both St. Thomas' and Moorfields Hospital. In this city the ravages of war and bombardment were evident. The operating theater at St. Thomas' had lost its large window, which was completely boarded up with wood. However, although instruments were few, he was able to work and operate. In 1946 Ridley established consulting rooms (private office) at 53 Harley Street, London, where he lived and practiced until 1989. During this period, his involvement with the IOL was, of course, the overriding preoccupation of his and Elisabeth's life. In 1951 he purchased a holiday cottage in Stapleford, Wiltshire, where he now lives.

Innovations Prior to the Intraocular Lens

Even prior to his momentous invention of 1949, Ridley showed foresight, creativity, and innovation in several areas: 1) He performed useful research in the field of tropical eye disease, especially onchocerciasis; 2) he was the first to televise eye operations, first in black and white (1948), later in color (1950); and 3) he devised a system of examining the inner eye by electronic methods (1949) and was the first to advocate the now popular technique of tele-diagnosis.

TROPICAL OPHTHALMOLOGY

In 1941 during his war assignment in (Ghana, Ridley was appointed part-time sanitation officer and headquartered at the capital city of Accra. At that time, Ridley met a British general, Brigadier G.M. Findlay, A.M.S., with whom he pursued investigations on onchocerciasis. Ridley, General Findlay, and one Captain John Holden journeyed to Fullsi, 90 minutes north of Accra, to study onchocerciasis (Fig. 2). Using a slit-lamp which ran off a 12 volt battery, they worked for two weeks. Ninety percent of the patients had onchocerciasis; ten percent of these were blind. Conditions were primitive and most of the work, even fundus painting and photography, was done by Ridley. His classic fundus painting, sometimes termed the "Ridley fundus" of onchocerciasis (Fig. 3) was completed in Accra after his return from the Bush. The attention he called to this disease constitutes one of Mr. Ridley's major contributions. His monograph, "Ocular

Onchocerciasis," published in 1945 in a supplement of the *British Journal of Ophthalmology*, was a landmark.

Ridley also treated ocular leprosy, a disease commonly regarded as incurable. He performed what he felt may have been the first successful corneal graft on a leper. Finally, his experience with vitamin A deficiency in blindness led to further post-war efforts to treat this condition. These efforts in tropical ophthalmology led to his early involvement with the Royal Commonwealth Society for the Blind, led by Sir John Wilson, a major consortium of government and non-governmental organizations dedicated to fighting blindness, especially in the developing world.

TELEVISING EYE OPERATIONS"

Ridley recalls,

At St. Thomas' Hospital we were able to show the very first television of eye surgery, first in monochrome in 1948 and by 1950, in full colour. Audiences at St. Thomas' Hospital saw these televised eye operations with the cooperation of Marconi's Wireless Telegraph Company and Pye Electronics Company. When the very first color appeared, quite good pictures were produced and Pye offered to sell the first color TV in England to me or St. Thomas' Hospital for, I think, £12,000. Perhaps I made a mistake in not purchasing it for the hospital and taking the opportunity to demonstrate eye operations in detail, but money was in short supply, and the complicated and unwieldy apparatus required a full-time technician.

EXAMINATION OF INNER EYE BY ELECTRONIC METHODS

Ridley hoped that better examination of retinochoroidal abnormalities might one day be possible by electronic rather than plain optical methods. He envisioned using such a technique to better understand such diseases as age-related macular degeneration, still one of the most common causes of irreversible visual loss. He experimented with these procedures prior to 1950.

Cooperating again with Marconi's Wireless Telegraph Company and Pye Electronics Company, and with additional help from John Pike of the Rayners Company and Peter Styles of St. Thomas' Hospital, fundus pictures were produced. The first pictures were obtained with indirect ophthalmoscopy transferred onto an electronic apparatus and later by the "Flying Spot Ophthalmoscope." Says Ridley:

Fundus pictures good enough to have been televised to other cities were produced. However, with the apparatus then available, more detailed examination of the inner eye was not achieved. We hoped to try selected wave lengths, etc., but had neither time nor money to spare. My great teacher, A.C. Hudson (Huddy) of St. Thomas' Hospital, did not support my attempts to produce electronic

retinoscopy (or later intraocular lens implants, for that matter) but we remained the best of friends.

Monochrome fundus pictures were produced and shown at the Oxford Congress in 1950, along with full color televised operations conducted earlier at St. Thomas' Hospital.

Among important advances made in ophthalmic surgery in this century have been the introduction of the IOL, the operating microscope with sophisticated microsurgical techniques, vitreo-retinal procedures, laser technology, and refractive procedures. Most of these developments came about when the ideas and efforts of many different scientists were combined and many individuals share credit for these important developments. However, Harold Ridley stands alone as the inventor and first planter of the IOL.

Not until the late 1970s and 1980s did Ridley begin to receive appropriate honor and credit for this original achievement. Most of the years between 1949 and the 1980s were difficult. For over three decades he was supported by a very few visionary individuals, but defamed by many. Fortunately, he has lived to see the vast benefits he has provided to humanity with his invention.

THE IDEA AND PREPARATION

Cataracts had been treated for centuries using procedures such as couching and various forms of intra and extracapsular extraction (ICCE, ECCE). Avoidance of complications and attaining a high quality postoperative visual rehabilitation remained a difficult problem. The classic means of correcting postoperative aphakia with thick spectacles had been less than satisfactory because of visual distortions and aberrations inherent in high-powered lenses. Apart from contact lenses, which were developed in this century, aphakic correction had changed remarkably little in hundreds of years. No doubt many ophthalmologists had for decades understood the tremendous optical advantages that an artificial replacement lens inside the eye could provide. However, Ridley was the first to act. Harold Ridley recalled some of the events that led to his first intraocular lens implant in 1949. In the 1930's while working as a house surgeon, he

....made inquiries to A.C. Hudson, and also my father, regarding a patient—a skilled man who lost the lens of one eye. This was almost equivalent to complete loss of the eye, except for unfocused visual field. This led to thoughts of an intraocular prosthesis, but I had to get full consultant status established before any action could be initiated. At that stage [house surgeon] I paid little attention to aphakia, but it was evident that an attempt to cure the many defects of

Daviel's 1748 (ECCE) surgery should be attempted. I soon became acutely aware that the cataract operation without a replacement lens was an incomplete, only half-finished operation.

One day, perhaps in 1947, a routine list of operations was performed. At the end, a student who had never before seen a cataract said, "It's a pity you can't replace the cataract with a clear lens." He was told that this was not usual, though many people, including myself, had suggested this project. However, no one had the temerity to take action.

The name of this student remained unknown or forgotten for many years until Ridley was informed by Jimmy Phillpotts, an ex-registrar (resident) of his, that the student's name was Steve Parry. Parry, who became a general practitioner in the North of England, therefore, at long-last receives credit for stimulatory action. There had been sporadic, mostly unverified, reports of previous attempts to implant either replacement lenses from cadavers or glass lenticular implants. However; any previous experimental work, if any, was not known to Ridley in 1949. Indeed, even up to the present, there is still no reliable evidence that any work other than Ridley's had been performed. Ridley recalls,

Before attempting to pioneer intraocular implants some tactical decisions were necessary calling for the greatest caution and courage. Secrecy was essential. Powerful colleagues, who had shown hostility to the idea of putting a foreign body in the eye, were known to exist. Most surgeons were satisfied with simple lens extraction. They considered aphakia a necessary part of the price to be paid for restoration of some measure of sight. Many found extracapsular surgery difficult and would not want to add the problems of a more complicated procedure. They feared the possibility of rejection of the prosthesis or of chemical or pathologic reactions, including even sympathetic ophthalmia. In the face of inevitable antagonism from world ophthalmology, to have any chance of success the greatest care had to be taken to foresee problems. After the most careful consideration, the site of implantation, the composition, size and shape of the implant, and, not least of all, legalities had to be thought out.

After months of secret thought, I called my friend John Pike, the optical scientist at Rayners of London with whom I had recently worked on electronic ophthalmoscopy. I suggested that we meet in my car after completing our routine duties that day. So it came about that two men sitting in a car in Cavendish Square one evening devised all the main principles of a new operation. We then thought this would benefit only a few cataract patients because it was probably too complicated and dangerous for many surgeons then equipped with only 19th century instruments and medication. We determined that the site for the prosthesis should be, if possible, just where nature had placed a biconvex lens throughout the animal kingdom. The accessible anterior chamber site had been carefully considered but rejected. Extracapsular extraction was preferred to the more fashionable intracapsular because it produced a 'stronger' eye, with the intact posterior capsule

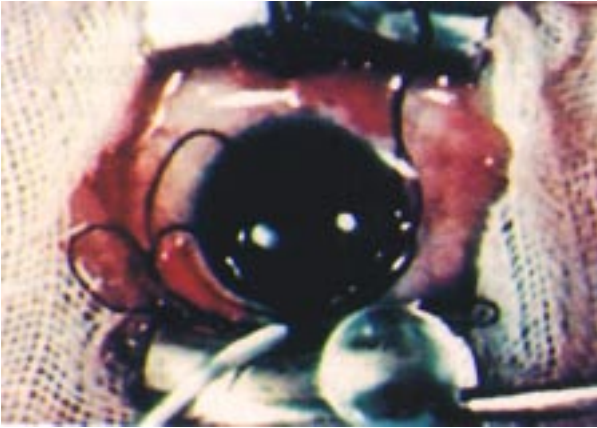


Fig 4. Photograph extracted from an original film and subsequent video tape of Ridley's eighth IOL implantation, performed at St. Thomas' Hospital, May 8, 1951. Although the film is aged and the clarity is imperfect, the plastic biconvex disk is clearly visible in the upper center of the photograph held by forceps. The lens opacity has been removed by ECCE and the actual insertion is occurring. This patient had 20/20 vision postoperatively. Note the relatively large 5-0 silk sutures and the gauze meshwork covering the operating field.

acting as a bulkhead within the globe.

The choice of material for the new lens lay between glass, a commercial quality of polymethylmethacrylate (PMMA, plexiglass, acrylic), and a mineral such as quartz. Glass and PMMA were relatively inexpensive and easy to fashion into shapes, and had good optical qualities.

Ridley drew on prior observations as a military surgeon that both glass and acrylic, under certain conditions, appeared to be inert within body tissues. During World War II some airplane cockpit and gunnery canopies were fabricated from glass and PMMA. When a canopy was shattered by gunfire, fragments of this material sometimes penetrated the eyes of the flight crew. Ridley observed that "unless a sharp edge of the plastic material rests in contact with a sensitive and mobile portion of the eye, the tissue reaction is insignificant."

This observation has become one of the most important principles now universally applied to modern lens design and implantation. Well into the 1990s many IOL designs were manufactured with poorly polished, sharp edges – an all-too-common cause of hemorrhage and inflammation.

The story about the airplane has often been questioned and has been written off as mythology or legend. Ridley states that the story is true, but overplayed as a "good item for the press." However, he noted that these observations provided an opportunity for good "preclinical" study. Dr. M. Park-Ross of Durban, South Africa, a young resident who participated in the first

cases, clearly recalls the mention and discussion of this event (personal communication to DJA, 1991). In addition, Peter Choyce, who assisted Ridley in his second case at Moorfields in early 1950 (three months after the first case) mentioned this observation in his 1964 monograph on IOLs.

The final choice of biomaterials was PMMA. Ridley explains why:

PMMA was light, with almost the same specific gravity,



Fig 5. Top: On routine examination of this 72-year-old woman in 1983, her ophthalmologist was surprised to find a Ridley implant. The patient had received the implant in the USA in 1953 when she had a traumatic cataract removed. She had been warned that the "new device" might restore her vision¹, but that she would risk losing her vision completely if the device were rejected. Thirty years later the patient's media were clear and vision was 20/25. (Reprinted from Matthews I: Letter. *Surv Ophthalmol* 29:230, 19X4, with permission of the author.) Bottom: (Gross photograph from behind (Miyake view) of an eye obtained post-mortem with a well-centered Ridley IOL. This patient had bilateral implants with subsequent excellent vision for two decades prior to death.

1.09, as aqueous humor; so this material was chosen by good fortune for the very first lens implant at St. Thomas' Hospital.

Sterilization was a major problem, since modern gas and gamma ray sterilization had not yet been discovered. It could not be physical because autoclaving distorted perspex (PMMA). Since chemical sterilization was necessary, the chief pharmacist at Moorfields was consulted and he suggested Cetrimide. Later it was found that a small quantity could be absorbed by PMMA. Indeed, some physicians subsequently implicated this agent as a cause of postoperative inflammation. A search had to be made for a better sterilizing agent.*

After selecting the site and material for the new lens, consideration had to be given to the optical effect required. Expert knowledge was provided by John Pike. He enthusiastically and repeatedly provided important technical assistance. First, he reported that the commercial PMMA which I had selected was not sufficiently pure to be inserted into all eye. He then consulted with his friend, Dr. John Holt, at Imperial Chemical Industries (ICI), and requested that he produce a carefully balanced PMMA containing no free monomer. They succeeded, utilizing catalysts and other substances, to synthesize a suitable plastic, first named Transpex I, later Perspex C.Q. (Clinical Quality). This has proved entirely satisfactory throughout the world and is still in Common usage today. The optical properties of the new lens required calculations. The work of the Swedish ophthalmologist and Nobel Laureate, Allvar Gunstrand, was consulted about twenty years after his death.

To prevent colleagues from saying it was a commercial venture, all three originators (Ridley, Pike and Holt) agreed to abandon any financial reward and keep the project purely scientific. Nobody made any money! This was a great sacrifice for firms such as Rayner and I.C.I. who needed to earn their living. Rayners charged me only cost price, less than one pound sterling for the early implants. Other firms who came in years later made vast fortunes from our early work.

I was most anxious to avoid mistakes which may have resulted from taking shortcuts. Two factors caused a project delay of about 1 year: 1) the careful addressing of possible problems, and 2) the rarity of volunteers who had to have one perfectly normal eye and be prepared to accept some unknown risk.

Ridley's first IOL operation was performed on a 45-year-old woman at St. Thomas' Hospital in London on November 29, 1949. The cataractous crystalline lens substance was removed by ECCE and the biconvex IOL was placed behind the iris onto the anterior surface of the posterior capsule. Ridley did this first implant in two stages—first the ECCE, then the implant three months later. His goal was to ensure that the eye was quiet after the ECCE so as to not to compound and confine any reaction caused by the

* Years later, in 1957, Frederick Ridley (no relation to Harold Ridley) developed The wet-pack sterilization technique, utilizing caustic soda neutralized by bicarbonate of soda just before implantation This was used for many decades, until ethylene oxide sterilization was developed.

implant itself.

Because the calculations for the anterior-posterior dimensions of the Ridley IOL were apparently based on measurements of the human crystalline lens, not properly accounting for the differences in refractive index between human lens protein and plastic, the initial lens was too thick. The first patient's refraction revealed a high myopic over-correction of over 14 diopters. However, her central Snellen visual acuity still improved to 20/60.

Encouraged by the initial anatomical success with his first patient, Ridley performed a second implant at Moorfields' Hospital in 1950.* Unacceptably high myopia again ensued, and appropriate alterations in the dioptic power of the IOL optic were made. Fortunately, the second series of computations produced about one diopter of myopia, which was satisfactory to both patient and surgeon, and for some time a standard lens was implanted in all cases.

Ridley implanted about one thousand lenses over the next several years (Figs. 5). Many patients who received implants from Ridley and his colleagues had successful visual rehabilitation. Figure 5 (bottom) shows a Miyake posterior view of a Ridley lens implanted after ECCE showing an excellent result.' He described the following exclamation of a patient still on the operating table as one of the most dramatic moments of his life." I can see the faces of all you gentlemen quite clearly," a comment which seemed to Ridley at that moment of comparable impact and originality to that of the archaeologist and discover of Troy, Heinrich Schliemann's statement, "I have gazed upon the face of Agamemnon."

However, complications did exist in a significant number of cases, 12 mainly from inadequate function after dislocation. Some of the lenses had to be removed. Ridley once said, after a lens dislocated in one patient who had had 20/15 vision for 12 years and five months, "I know of no surgical catastrophe which causes more anguish than the sudden and unexpected failure of a successful intraocular lens." It has long been held that inferior dislocation of the Ridley IOLs were due to excessive weight of the implant. However, our studies lead us to believe that the then commission technique of ECCE-leaving little equatorial support by the capsular bag in the absence of haptics – was the most important cause.

* Ridley notes: "Moorfields was very good too, and many who worked there probably thought of that the premier Eye hospital should have been the first to do implants. However, the necessary secrecy could not have been guaranteed, so that the first operation was done at S.T.H., but operations 2, 3, & 4 were at Moorfields, which seem. as fair to both as could be."

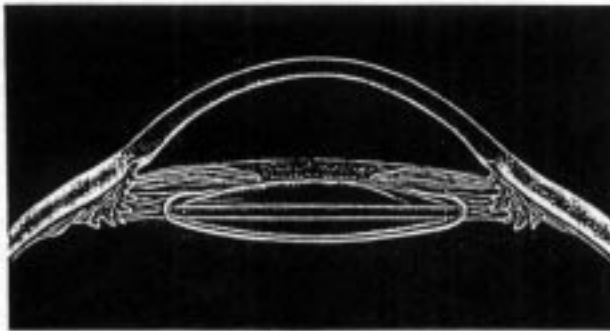
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AN ACRYLIC INTRA-OCULAR LENS

At the Oxford Ophthalmological Congress, July 6th, 1951, and in the March 1952 issue of the British Journal of Ophthalmology, Mr. Harold Ridley described the introduction into the eye, in the place of the crystalline lens removed for cataract, of a substitute crystalline lens made from Perspex.

A



C

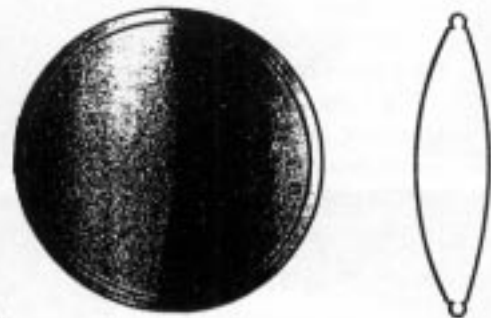


Fig 5. A: Reproduction of a portion of an early brochure describing the Ridley lens. (Courtesy Ian Collins, Director, Rayners Intraocular Lenses, Ltd., East Sussex, England) B: Schematic illustration of a sagittal section of an eye illustrating the ideal placement of a Ridley biconvex disk IOL onto the posterior capsule. In reality, following the early can-opener type anterior capsulectomies performed at that time, there was probably very little equatorial capsule left; therefore, the lenses were more correctly placed "on the bag" rather than "in the bag." This lack of equatorial support was a major reason for the relatively high incidence of decentration of the early Ridley lenses. (From reference 1, Krystyna Srodulski, artist) C: Frontal and sagittal sketches of the biconvex Ridley posterior chamber IOL.

PROFESSIONAL REACTION

Ridley's first presentation of the new procedure was given at the Oxford Ophthalmological conference on July 9, 1951, at which time the implant in the patient first had remained in place for 20 months. Even though there was a danger that someone else may have heard about his experiments and could have acted, publicized and falsely claimed priority, Ridley delayed the report of the operation for this long period. He also believed that delay was necessary for the safety of the patients, as there was danger that other surgeons would have rashly, prematurely, and inappropriately performed the operation.

Since the operation was revolutionary rather than evolutionary it seemed sure to encounter widespread criticism, so we decided to keep the idea secret for a while. To forestall hostile criticism leading to rejection I hoped to show IOL cases of two years duration to prove that the operation was practical. However, the news leaked prematurely when a patient, who had heard about another case, accidentally consulted another surgeon, Frederick Ridley, believing that he was the right surgeon. Therefore, the publication was delayed only from November 1949 to July 1951, and not the full two years intended.

He recalls that first presentation at Oxford (Fig 6):

In spite of my request for favorable timing, the Hon. Secretary of the Oxford Congress arranged presentation of this paper just after the lunch break, when some members had not returned to the lecture hall. Two delighted implant patients had travelled to Oxford in my car, one refusing to agree that the time on the clock was 5 minutes to the hour, insisting rightly, without glasses, that it was .3 minutes to the hour. These patients, one whose result was perfect, 6/6 unaided and 6/5 with - 0.5 OS, aroused interest and disbelief: Sir Stewart Duke-Elder and others repeatedly refused even to look at my demonstration patients. However John Foster of Leeds kindly offered his congratulations and reported that he had written as a joke, in the Leed's Student Medical Journal, of a fictitious operation regarding an intraocular prosthesis. He was very glad to learn that an Englishman had actually pioneered the innovation. There were a few further trifling comments and then suddenly the Deputy Master foreclosed the discussion, an action for which he apologized later that day. My wife and I decided to miss the dinner arranged and went off to

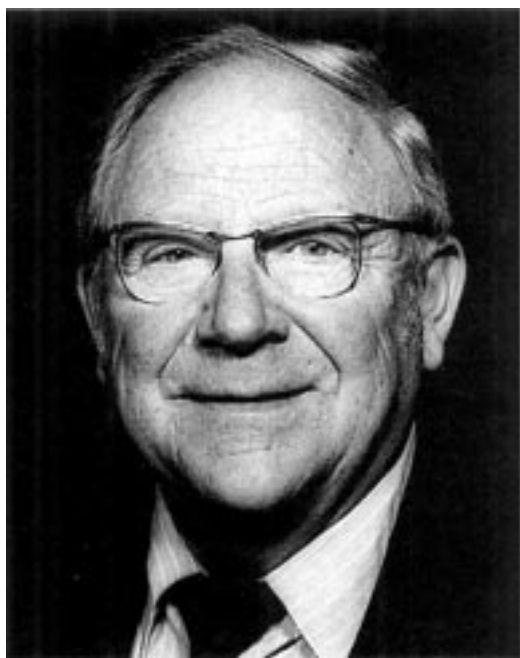


Fig 7. D. Peter Choyce, South-end on-sea, England, a participant in the early operations and close colleague and supporter of Ridley. Choyce and Ridley were instrumental in reviving and indeed keeping implants alive at a crucial time when the future of this operation was in doubt – in particular at a meeting of the International Congress of Ophthalmology, Paris, 1974.

dine alone.

Ridley's first article relating to IOLs was published in 1951, in the Transactions of the Ophthalmological Societies of the United Kingdom. Like Roentgen's original publication on x-rays in the 1890s, Ridley's description of the general principles of the operation were amazingly thorough and complete. His description of the goals of the procedure, the implant, and the steps of the surgical techniques showed great insight and most of his principles remain valid today.

In his own opinion, the only serious omission in this first paper was the lack of a solution of achieving stable fixation of the implant. Indeed, this is a problem that took over 40 years to solve. Only after realizing the advantage of in-the-bag (capsular) fixation of posterior chamber IOLs and developing appropriate surgical techniques to accomplish this was this goal achieved. Although Ridley had a handful of early supporters throughout the world, including Peter Choyce and Edward Epstein (who did his first implant in November of 1951), he had numerous detractors. In the United Kingdom, even at St. Thomas's Hospital and Moorfields Eye Hospital, the two institutions where he performed his early implants, the importance of his work was not recognized for some time. One of the most vehement of Ridley's detractors was Sir Stewart Duke-Elder. Steven Shearing has noted that, "Initial

enthusiasm for intraocular lenses was followed by scorn and then dismissal. Rather than seeing surprising relative success in these early attempts, surgeons focused on the frequency of failure. A few surgeons even built careers on the effort to consign intraocular lenses to the wastebasket of ophthalmology." Ridley noted: "I met great opposition when developing implants, partly because many failed to appreciate the very adverse optical effects of aphakia. Perhaps there was considerable jealousy." His first lecture in the United States on his innovation was given in March 1952 at the annual meeting of the Chicago Ophthalmology Society. He reported that his presentation was received "quite enthusiastically" and recalls, "I gave away about six lenses. Warren Reese, destined to be the first American implant surgeon, flew his private plane to Philadelphia and inserted an IOL the next morning at Wills eye Hospital."

On October 12, 1952, Ridley presented a paper at the 57th session of the American Academy of Ophthalmology and Otolaryngology in Chicago. Ridley and his procedure were met with great hostility by several skeptical ophthalmologists including Derrick Vail, M.D., Editor-in-Chief of the American Journal of Ophthalmology. Although Vail softened his tone in subsequent publications, his comments at that meeting were quite severe.

In spite of Mr. Ridley's remarkably successful run of cases here reported, the operation is one of considerable recklessness. Its hazards far exceed the little that is gained in the way of ocular comfort to the patient and the questionable advantage of binocular vision obtained at such an obvious risk.

Until further work is done and more time has elapsed and more of the risks involved I do not want such an operation performed on myself nor can I advise it for my patients, willing as they might be to undergo the additional hazards of which they can have no true conception.

It is unfortunate that, beginning with Duke-Elder and Vail, several prominent surgeons in the 1950s and '60s, many representing the academic establishment in Europe and the United States, treated Ridley and his lens with severe disdain, as Ridley discussed in his 1993 Gullstrand lecture. While it was certainly reasonable for those in the ophthalmology establishment to approach the IOL procedure with caution and conservatism, their reactions created an unhappy situation, not only in human terms because of the discourteous and unpleasant actions directed toward Ridley, but also because research advances of this surgical procedure were often limited by the prejudice expressed against it. Ridley recalls:

Peter Choyce courageously became a fervent supporter of IOLs, in spite of having received a personal warning from



Fig 8. Founding members of the International Intraocular-Implant Club (IIIC), July 14, 1966, in London. From left to right front row: Lurie Boberg-Ans, Cornelius Binkhorst, Peter Choyce, Harold Ridley, Strampelli, Edward Epstein, and Mrs. Boberg-Ans. Second row left to right las, Brown, Rubenstein, Warren Reese and Lurie.

Duke-Elder against cooperating with me – a threat that if he continued to support me he would never get a consultant post. Peter Choyce became the first surgeon to show courage and confidence, but was made to pay a heavy penalty for daring to support us.

Choyce (Fig 7), in a personal communication of October 27, 1994, reviews the situation as follows:

I finished my resident training at Moorfields in 1951 and then became a senior lecturer at the Institute of Ophthalmology presided over by Duke-Elder. On several occasions he questioned me closely about Ridley's IOL patients and he made it quite clear that he thought the concept of lens implantation was misguided and had no future. He expressed the view that he was sorry to see a young man, of whom he had such high hopes, devoting his energies to such a topic when there are so many other interesting things to which he could apply his talents. Eventually when it became clear that I was intellectually convinced that Ridley was on the right track, he said that in that case, I could no longer count on his support to obtain a consultant post.

Ridley was ostracized for a time from the mainstream of ophthalmic surgery and was forced to abandon his original posterior chamber lens. Mainly because of the threat of legal charges being brought against him and others, widespread application of his innovations and concepts, especially an overall acceptance of the advantages of posterior chamber implantation, considered routine today, was postponed for over a decade. Ridley reflects:

One extremely worrying matter was the fear of a charge of malpractice being brought against me in which I could rely on the support of very few colleagues. British ophthalmology was led by a powerful, strongly antagonistic rival. So, sadly, Britain lost her claim to be the undisputed pioneer of the revolution in ophthalmology which arose in the second half of the 20th century.

Many ophthalmologists and their patients experienced unfavorable results during the many years of often chaotic experimentation and defective IOL design and manufacture prior to the current re-establishment of many of Ridley's principles. Some lenses between the mid-1950s and mid-1980s were of such poor quality that it was often sarcastically joked that they would have made better IUDs than IOLs. Ridley recalls:

Surgeons who were less meticulous often ran into trouble and many abandoned the project in disgust. There was little evidence of any colleague supporting the research-club project until Peter Choyce, who assisted at Moorfields with implant operations numbers 2,3, and 4 (years before he became a consultant ophthalmologist), adopted the cause. The first meeting of the International Intraocular Implant Club (IIIC) was held in London on July 14, 1966. Organized by Choyce (Fig. 6), it was attended by only 16 ophthalmologists (Fig. 8). It was not long, however, before several countries set up national implant societies to spread the advance in cataract surgery.

However, major setbacks occurred. José Barraquer of Barcelona, enthusiastic at first, had several problems after doing anterior chamber IOL implants in phakic patients in an attempt to cure myopia. This led to a subsequent condemnation of implants in general that spread through the world. We now know that many of these complications were largely due to the very poor designs and manufacture of the IOLs available in the 1960s and '70s. Even into the late 1980s much of the academic establishment in ophthalmology was firmly against the clinical use of IOLs. In 1969, Duke-Elder wrote,

It can be well argued that while the results of a cataract extraction are usually so good and the use of contact lenses so safe and easy (in selected cases) it is perhaps unwise to gamble on further surgical procedures (IOL insertion)



Fig 9. The Ridleys at their retirement cottage, 1987.

which require considerable specialized technical skill and a healthy eye on which to operate, the results of which in the absence (at present) of long term observations are somewhat problematical.

Some surgeons referred to the IOL as a "time bomb." The National Eye Institute showed little interest in this device and never funded an American-based research project on IOLs. In the first two decades after his discovery the resistance to Ridley and his invention was highly vocal. By the 1970s and '80s, as the success of this device became assured, although animosity still continued in some quarters, it became manifest more in the form of a subdued resentment.

Many of Harold Ridley's concepts were amazingly accurate and the thought and preparation that culminated in the first lens implantations were major research accomplishments. Had our superior modern surgical instruments and techniques been available when he introduced his initial IOL design, (e.g., modern anterior capsulotomy techniques such as continuous curvilinear capsulorhexis, viscoelastic surgical adjuncts, and capsular IOLs, it is probable that the history of IOLs would have been radically altered.

Intraocular lenses have evolved through five generations, and a sixth, which emerged in the late 1980s will propel us into the 21st century. These

generations are:

- I Ridley lens, 1949
- II Early anterior chamber lenses, 1952-1962
- III Iris supported lenses, 1953 – 1973
- IV Modern anterior chamber lenses, 1963-present.
- V Modern posterior chamber lenses, 1975-present.
- VI Capsular intraocular lenses designed specifically for implantation into the lens capsular bag, including both standard PMMA designs and pliable soft (foldable or expansile) IOLs.

Generations V and VI, where in-the-bag fixation has become the dominant mode of implantation, represent the culmination of research data gained over the last 45 years and fulfill Ridley's wish of implanting the prosthesis into the site "where nature had placed a biconvex lens throughout the animal kingdom."

The modern "capsular" lenses are designed to be placed in the capsular bag and are especially amenable to be implanted with modern "capsular" surgery, e.g., hydrodissection, capsulorhexis and phacoemulsification – preferably associated with small entrance incisions. "Capsular" IOLs are either modern one-piece all PMMA haptic designs or – even more futuristic—are foldable "soft material" IOLs that can be implanted through very small incisions—3.5mm or less.

Modern cataract surgery is not only a means of removing and replacing an opaque lens, it is now essentially a refractive procedure. With appropriate lens power calculations, sometimes combined with corneal molding via incisions or suture alterations, a patient's refractive error can be eliminated.

Recognition of Ridley's Contribution

In 1976 Ridley was honored by hundreds of Surgeons at the annual meeting of the American Academy of Ophthalmology and Otolaryngology in San Francisco. In 1987 he was honored at a meeting of the European Implant Lens Council in Jerusalem. It was just prior to this meeting that one of us (DJA) first met the Ridleys at their retirement cottage at Stapleford near Salisbury in Wiltshire in 1986 (Fig. 9). This meeting followed correspondence regarding data from our Center for IOL Research (at that time in Salt Lake City) that had largely reconfirmed many of Ridley's original concepts." By the mid 1980s Ridley was being vindicated worldwide in at most all respects.

Ridley received his highest honor in 1986 when he was elected a Fellow of the Royal Society of London. This society was chartered in 1662 by King Charles II, and

Sir Isaac Newton was an illustrious early member. This society is reserved for individuals who have made scientific contributions of the highest order.

Ridley's first academic honor was the conferring of an honorary doctorate degree, Doctor of Humane Letters (DHL), from the Medical University of South Carolina, Charleston, in May of 1989. In 1988, an annual Ridley Lecture was established by the European Intraocular Implant Lens Council. Ridley, along with Cornelius Binkhorst, Peter Choyce, Edward Epstein, and S. N. Fyodorov, received special acknowledgement at the 1989 Annual Meeting of the American Society of Cataract and Refractive Surgery in Washington, D.C. He also received a special guest award at the American Academy of Ophthalmology in Atlanta in 1990.

In Stockholm in 1992 Ridley received the Gullstrand Medal, which is presented every 10th year to the scientist who has made the most significant contribution in the field of ophthalmology. The Gonin Medal was conferred to Ridley at the meeting of the Gonin Society in Lausanne, Switzerland, in May 1994; this honor was reaffirmed at the International Conference of Ophthalmology in Toronto in July 1994. The Gonin Medal, named after the Swiss Ophthalmologist, Jules Gonin, who elucidated the pathogenesis and recommended principles of treatment of retinal detachment, is one of the supreme awards in world ophthalmology, awarded every four years. Ridley is the first individual in a non-retinal subspecialty to receive this honor.

Comment

It is fortunate that Harold Ridley has lived to receive appropriate recognition for his invention of the intraocular lens. He has been able to see its deep penetration, especially in the industrialized world where technology and funds have been available for wide dissemination. Ridley takes pride in the enormous growth of his specialty and the benefits provided by his invention.

I have seen ophthalmology improve from a relatively small, peripheral subspecialty to become one of the major parts of a hospital, helping a large proportion of elderly patients. I have indeed, become one of them myself,* lucky to live long enough to personally benefit from the enormous improvement in cataract surgery. I am almost certainly the only surgeon ever to design a new operation that was to be used in both of my own eyes some 40 years later.

The economic implications of Ridley's invention have been enormous. Various incalculable costs, such as loss of work time due to visual disability, as well as morbidity due to visual loss or frank blindness, have decreased. It is ironic that in some countries,

particularly the United States, the procedure of cataract surgery-IOL implantation (especially in conjunction with phacoemulsification) has been so successful and, unfortunately, so costly that its widespread usage has strained government health care systems. This is most notable in the federal Medicare System in the USA. Because of the large surgical volume, primary cataract extraction and IOL insertion represents one of the greatest expenditures among all operations in medicine! Secondary Nd: Yag laser capsulotomies for posterior capsule opacification also represent a major cost to the health care system. Although clearly never expected or dreamed of by Ridley, his invention – and the inevitable evolution toward refractive surgery – have been major factors that now are forcing rapid changes in health care delivery. The economic changes began in earnest in the mid-to-late 1980s and continue.

There is no doubt that someone else would have invented the IOL at a later date if Ridley had not done so. However, there is no telling when – probably at a much later date. Looking back, Ridley reflects:

Was intraocular implant surgery started a generation too soon? No, the time was both right and ripe. Immediately after a major war (World War II) many were accustomed to accepting risk of injury. If implants had not started in 1949 they might have been delayed for yet another forty years.

Ridley may not live to see an even broader application of his device, namely introduction of IOLs on a widespread scale into the developing world. Forty million people in developing countries are functionally blind – over half of them from cataract. To date, implantation of IOLs on a wide scale in the rural areas of these countries is still an impossible dream, mainly for socioeconomic reasons. These patients remain destined to suffer as statistics amongst a 20 million person backlog of unoperated cataract patients, or as operated patients with crippling visual disability because of poorly functioning aphakic spectacles, which are often broken or lost.

Even at the time of this writing there are many who argue against the use of IOLs in the developing world. It would be a spectacular legacy to Harold Ridley – whose heart and intellect were strongly devoted to the problem of tropical medicine and blindness in the developing world – to accelerate and expand efforts to provide the benefits of IOLs to needy individuals throughout the world. Young residents and

* Ridley himself received in-the-bag implants in 1989 and 1990, performed by Micheal Falcon of London, with correction to 20/20 OU.

practitioners today implant IOLs routinely and with ease, not realizing the extraordinary struggle that Ridley and many others had to undergo for many years to develop this technique. We all have short memories.

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