The Beginning of Modern Cataract Surgery

The Evolution of Small-Incision Cataract Surgery

A short history of ophthalmologists' progress.

BY SAMUEL MASKET, MD

In the 1960s, ophthalmologists considered removing a cataract through a 3-mm incision to be impossible. The ingenuity and perseverance of Charles Kelman, MD, led to the development of phacoemulsification, which, in combination with advances in bioengineering, and surgical technology, transformed the procedure from a fringe concept 35 years ago into the most viable tool for cataract surgery. Today, 95% or more of cataract surgery involves phacoemulsification. The progress from then to now required the creation of a surgical industrial complex that has produced a highly cost-effective, modern miracle of sight restoration that helps many senior citizens maintain their independence. This article traces the evolution of ultrasonic, small-incision cataract surgery.

THE 1960S: THE BEGINNING

When Dr. Kelman began performing emulsification surgery, ophthalmologists did not fully understand corneal physiology, and they did not appreciate the fact that corneal clarity depends on a healthy (and nonregenerative) corneal endothelium. Protective viscosurgical agents (eg, ophthalmic viscoelastic devices [OVDs]) and vitrectomy techniques (other than "open sky") did not exist. Consequently, if the lens nucleus dislocated posteriorly during surgery, the eye was likely functionally lost. For that reason, maintaining the posterior capsule was of the utmost importance.

Dr. Kelman devised a method by which to prolapse the nucleus into the anterior chamber (similar to the present-day phaco flip technique) for emulsification. The maneuver required a generously sized anterior capsulotomy, which he created with a large cystotome in a "Christmas tree" or triangular fashion. He then used the cystotome to impale the nucleus and bring it forward into the anterior chamber via a "tire iron" maneuver under air. At this point, he used a one-handed technique to emulsify the nucleus in the chamber. Central to success with this maneuver were a dilatable pupil and an anterior capsulotomy that allowed the surgeon to move the nucleus anteriorly for extraction from the capsular bag.

THE 1970S: THE POSTERIOR MOVEMENT

Visual Rehabilitation

Early adopters of phacoemulsification found that corneal edema was a clinically significant problem, and they fre-

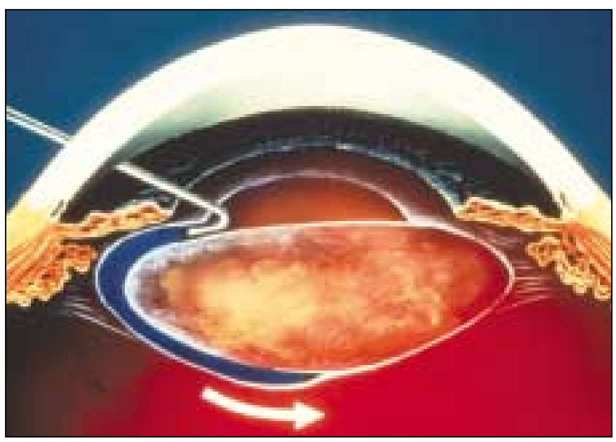

Figure 1. During hydrodissection after the creation of the capsulorhexis, the fluid wave creates a plane between the cortex and capsule or the epinucleus and cortex, thus allowing the surgeon to rotate the nucleus within the confines of the capsular bag.

quently experienced difficulty in maneuvering the lens nucleus into the anterior chamber. Pioneers such as Richard Kratz, MD, and Robert Sinskey, MD, in particular, began developing variations on the original surgical method. Their idea was to relocate the emulsification action away from the endothelium in order to protect the cornea and permit rapid visual rehabilitation. The best measure of surgical quality is the patient's vision during the early postoperative period, as Robert Osher, MD, has emphasized. Protecting the corneal endothelium is essential to achieving that goal.

Sinskey's Method

Dr. Sinskey developed a one-handed method in which he gently shaved or sculpted the nucleus within the posterior chamber after creating a large can-opener capsulotomy. After sufficiently debulking the lens, he could remove the softer posterior plate from the posterior capsule and bring it forward through the generously sized capsulotomy without endangering the posterior capsule.

Kratz's Method

Although Dr. Sinskey's method maintained corneal clarity and worked well in his talented hands, it did not eliminate the risk to the posterior capsule, particularly because the anterior capsulotomy could easily extend peripherally and posteriorly. In response, Dr. Kratz developed the concept of iris plane phacoemulsification. Employing a two-handed maneuver, he tipped the superior pole of the lens nucleus forward to the level of the iris. After creating a generously sized can-opener anterior capsulotomy, Dr. Kratz sculpted a small crater in the central nucleus. Next, using a spatula as a lever in the crater (through a sideport incision with his second hand), he steered the nucleus forward by discontinuing fluid inflow and allowing the eye to soften. By manipulating the phaco tip with one hand and using the spatula in his other, Dr. Kratz freed the superior pole of the nucleus from the confines of the capsule and brought it into the iris plane. He then rotated and ultrasonically chiseled the nucleus while holding the nuclear remnant above the capsule with the spatula and using ultrasound to remove the material from the "outside in."

The Sinskey and Kratz methods made phacoemulsification easier for surgeons to learn and thereby enabled more ophthalmologists to adopt the procedure. William Maloney, MD, systemized Dr. Kratz's iris plane method for the "Three Steps to Phaco," an instructional program widely disseminated by equipment manufacturers and an enthusiastic traveling faculty. Many of today's leading cataract surgeons were members of that original faculty. As a group, they prompted many surgeons to begin performing phacoemulsification, and they were responsible for the development of many innovative surgical techniques.

THE 1980s: THE CAPSULORHEXIS ERA

Technical advances furthered the surgical science of phacoemulsification and attracted more physicians to the procedure. The first OVD brought to market, Healon (Pfizer Inc., New York, NY), facilitated lens implantation and protected the cornea during phacoemulsification. Additionally, the development of the capsulorhexis increased the procedure's safety by reducing the capsulotomy's tendency to extend peripherally to the posterior capsule.

Nevertheless, the capsulorhexis presented a new challenge to surgeons. The typical can-opener capsulotomy allowed the ophthalmologist easily to elevate the lens nucleus or posterior plate and then emulsify the lens as a whole from the "outside in." By contrast, a circular capsulorhexis, unless atypically large, trapped the nucleus within the capsular bag and required the surgeon to emulsify the lens from the "inside out."

The difficulty of elevating the entire lens nucleus out of the capsular bag led surgeons to develop methods for dividing the nucleus and moving the pieces from the capsular bag into the deepest portion of the chamber for safe emulsification. Ophthalmologists devised nuclear subdivision methods in linear, circumferential, or combined forms. Additionally, hydrodissection evolved as a means of moving and rotating the nucleus within the capsular bag, thereby facilitating the subdivision process (Figure 1).

Howard Gimbel, MD, described linear division as *nucleofractis*, and John Shepherd, MD, developed the four-quadrant divide-and-conquer concept, which remains the most commonly practiced form of phacoemulsification (Figure 2). I. Howard Fine, MD, introduced circumferential nuclear subdivision into endonuclear and epinuclear portions with hydrodelineation. His method of chip-and-flip nuclear removal gained popularity among those surgeons less comfortable with manually splitting the lens nucleus.

Figure 2. The surgeon performs divide-and-conquer quadratic dissection for phacoemulsification.

Phacoemulsification grew

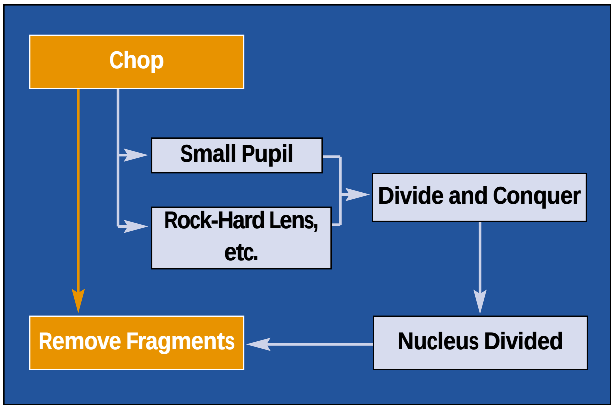

Figure 3. This algorithm of emulsification surgical styles emphasizes the chopping methods' efficient use of ultrasonic energy.

more popular during the 1980s, largely thanks to the introduction of OVDs and foldable IOLs, as well as the development of workable surgical methods.

THE 1990s: THE ERA OF REDUCED EMULSIFICATION ENERGY

The premise and promise of small-incision cataract surgery are to provide rapid visual rehabilitation and a stable visual outcome. Central to those goals are protecting the corneal endothelium by using retentive OVDs and exposing the cornea to low amounts of ultrasonic energy. Manufacturing technology and surgical techniques developed during this decade helped ophthalmologists to attain the aforementioned goals.

In my experience, 97% of patients in one study group with a variety of nuclear densities achieved clear corneas at 1 day postoperatively (unpublished data). These results were achieved partly through the modulation of emulsification energy in the form of bursts and/or pulses. My colleagues and I further reduced the amount of ultrasonic energy needed by using high-vacuum aspiration and chopping the lens nucleus.

As originally described by Kunihiro Nagahara, MD,[1] nuclear chopping uses high-vacuum ultrasound to impale the lens nucleus, and the emulsification tip firmly purchases the nucleus. The surgeon simultaneously places a sharpened tool (chopper) near the equator of the lens and draws it toward the phaco tip in order to chop or slice the lens into portions before emulsifying and aspirating them. Other surgeons have modified this so-called full chop (also known as *horizontal chop*) to create quick chop (also called *vertical chop*). Each method has its advantages and disadvantages, but both reduce the total amount of ultrasonic energy to which the anterior segment structures are exposed. Some surgeons preferred a hybrid method popularized by Paul Koch, MD, and called *stop and chop*. With this technique, the surgeon uses ultrasound to divide the lens nucleus into two pieces and then chops the heminuclei.

In an algorithm for nuclear emulsification (Figure 3), the direct line from chopping to the removal of lens fragments represents the shortest path and requires the least amount of energy. The surgeon's preference or surgical conditions may dictate an alternate, longer course that requires more ultrasonic energy, however.

THE 2000s: THE ERA OF ALTERNATIVE ENERGIES

Recently developed technologies have further reduced the amount of ultrasonic energy needed for cataract surgery. Digital ultrapulsing of ultrasonic energy (the WhiteStar system; Advanced Medical Optics, Inc., Santa Ana, CA) has been associated with lesser energy output and lower frictional heating of ocular tissue. The latter result has interested surgeons in bimanual microincisional phacoemulsification, in which the surgeon passes an unsleeved ultrasonic tip through a sub–2.0-mm incision. An infusion cannula/chopper delivers infusion fluid through a similarly sized incision.

Investigators have also developed alternatives to ultrasonic lens removal. Laser lens emulsification with various wavelengths, tip oscillation (NeoSoniX; Alcon Laboratories, Inc., Fort Worth, TX), the Sonic Wave (STAAR Surgical Company, Monrovia, CA), and pulsed fluids (AquaLase Liquefaction Device; Alcon Laboratories, Inc.) are all supposed to remove the lens without the attendant turbulence associated with ultrasonic energy. Although these modalities may be applicable to clear lens replacement surgery or the removal of early cataracts, I have found that none competes favorably with ultrasound's efficiency at removing denser cataracts.

CONCLUSION

The cataract surgery performed by today's ophthalmologists is a highly evolved form of the original concept, thanks to the ingenuity and perseverance of Dr. Kelman, the bioengineering of medical devices, and many ophthalmologists' refinement of surgical techniques. The resultant procedure significantly improves patients' quality of life at a remarkable value-to-price ratio. ■

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1. Nagahara K. Phaco chop. Film presented at: The International Congress on Cataract, IOL, and Refractive Surgery; May 1993; Seattle, WA.