COMMENTARY

How a jolt and a bolt in a dentist's chair revolutionized cataract surgery

Joseph L Goldstein

Cataracts are the major cause of reversible blindness throughout the world, affecting about 20 million people. Until 1970, cataracts were the leading cause of blindness in the United States. Today, in the United States and other industrialized countries, cataracts are no longer a significant cause of blindness. This achievement can be traced in large part to the development of a simple, small-incision cataract operation pioneered by Charles D. Kelman, this year's recipient of the Lasker Clinical Medical Research Award (**Fig. 1**). The outpatient procedure pioneered by Kelman, called phacoemulsification, has now become the most commonly performed elective surgical operation in the western world. In the United States alone, nearly 3 million Kelman-type cataract operations were performed last year[1].

Cataracts occur when the clear crystalline lens of the eye becomes clouded, resulting in partial or complete loss of vision. Although cataracts result from many conditions (such as trauma, genetic diseases and diabetes), the most frequent cause is the natural aging process. More than one-half of the population older than 65 years develops impaired vision caused by cataracts. There are no diets, drugs or eyedrops that will make a cataract disappear; the only treatment is surgical removal. Historically, cataract surgery is one of the oldest operations, second only to circumcision.

Before Kelman—inpatient cataract surgery

In 1970, before the era of Charles Kelman, the surgical removal of cataracts was a major ordeal, requiring a hospital stay of 10 days (if no complications occurred) and a convalescence of several months[2]. Typically, the patient underwent general anesthesia, after which a large, semicircular (180°) incision was made in the cornea to allow the entire lens to be grasped with a forceps and pulled from the eye in one piece. Eight or more sutures closed the incision, and the patient was kept on absolute bed rest for 3–5 days with both eyes occluded with patches. To restrict movement of the head, sandbags were placed along both sides of the head, and both wrists were bound with restraints to the bed. This enforced immobilization often led to mental disorientation, prostatic obstruction, bedsores and pulmonary embolism. As many as 20% of patients developed vitreous hemorrhage, macular edema, eye infections and retinal detachment. After discharge from the hospital, the eyes and lids remained red, swollen and irritated for as long as 6 weeks. The surgically treated eye had to be patched for several months, and the aphakic patient had to wait for as long as 6 months to be fitted with thick spectacle glasses.

In the early 1950s, an important advance in cataract surgery occurred with the invention of the artificial intraocular lens by Harold Ridley, an ophthalmologist at St. Thomas and Moorefield Eye Hospital in London[3]. Ridley's invention was conceptually quite radical and went against the long-standing dogma that a foreign body, such as a plastic lens, should never be placed into the delicate tissues of the eye. The vast majority of ophthalmologists were slow to embrace the use of intraocular lenses in their cataract operations. The full impact of Ridley's invention was not realized until the late 1980s, with evolving improvements in the design of more flexible types of intraocular lens. The demand for a better lens was stimulated in large part by the increasing use of Kelman's new phacoemulsification procedure, as described in the following paragraphs.

After Kelman—outpatient cataract surgery

In 1967, while Kelman was a staff ophthalmologist at the Manhattan Eye, Ear and Throat Hospital in New York City, he published an article describing a totally new approach that would, over the next 25 years, ultimately replace traditional inpatient cataract surgery with a much less intrusive and more curative procedure that could be performed on an outpatient basis[4]. Kelman called his procedure phacoemulsification (*phako* being Greek for 'lens'; *emulsi* for 'milked out'). In its currently practiced form[5–7], phacoemulsification involves making a small, self-sealing incision in the cornea (3° in contrast to the traditional 180°) and then inserting an ultrasonic probe, the vibrations of which (40,000 per second) break and liquefy the cataractous lens without damaging the surrounding tissues. The emulsified fragments of the lens are then suctioned through the sonic tip, and a foldable intraocular lens (made of acrylic or silicone) is inserted

Figure 1 Charles D. Kelman (1930–2004), recipient of the 2004 Lasker Clinical Medical Research Award died on June 1, 2004, several months before the Lasker Awards ceremony.

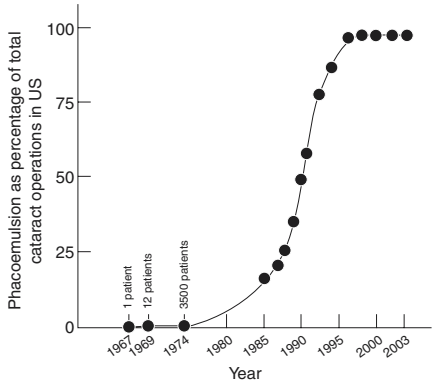

Figure 2 Rise in use of the phacoemulsification procedure for removal of cataracts in the United States from 1967 to 2003. The data from 1985 to 2003 are based on surveys of members of the American Society of Cataract and Refractive Surgery conducted annually by D.V. Leaming and published annually in the *Journal of Cataract and Refractive Surgery*. For the first survey (1985) and the last survey (2003), see references 12 and 1, respectively. The total number of cataract operations in the United States in 2003 is estimated to be nearly 3 million.

through the small incision. Once inside the eye, the flexible lens unfolds like a parachute, and visual acuity is typically restored to 20/20 or 20/40. There is no longer a need for the thick, unattractive and optically poor spectacles that were common in the pre-Kelman era.

The entire procedure, which can be done in 5–10 minutes, is performed on an outpatient basis under topical or intraocular anesthesia. Because the eyelids are not anesthetized, no eye patch is required and recovery is almost immediate. The genius of Charles Kelman—the discovery that small-incision phacoemulsification allows rapid, painless restoration of vision—is reminiscent of the genius of Ray Kroc, the founder of McDonalds. Kroc discovered that people like to be served in 60 seconds—a discovery that changed the eating habits of the entire world. Charles Kelman's discovery changed the operating habits of ophthalmologists.

An epiphanous moment in the dentist's chair

The idea for phacoemulsification came to Kelman in 1964 while sitting in his dentist's chair and having his teeth cleaned. A sudden jolt from the dental drill produced an epiphanous bolt from the blue. As Kelman writes in his memoir[8], "I sat in his chair, as he reached over, took a long silver instrument out of its cradle and turned it on. A fine mist came off the tip but the tip didn't seem to be moving. He applied the tip to my teeth, and I felt an exquisite vibration and heard a high-pitched sound." Kelman asked, "What is that thing?" The dentist replied, "An ultrasonic probe." "I knew this was the moment," Kelman wrote[8].

After this epiphanous moment came several years of intensive research on the eyes of cats and human cadavers until the phacoemulsification technique was first used on a patient in 1967. By 1969, Kelman had used his procedure to remove cataracts in 12 patients[9]. Between 1967 and 1973, 3,500 cataract removals by phacoemulsification had been performed in the United States, 500 of them by Kelman[10]. The vast majority of ophthalmologists viewed phacoemulsification as a radical procedure that totally challenged their conventional wisdom. In particular, they were shocked by Kelman's audacity in discharging his hospitalized patients on the same day as the surgery and permitting them to return to full activity on the first or second postoperative day[7,10,11]. Today, we take outpatient cataract surgery for granted, but 30 years ago Kelman's approach was heretical and was met with overt hostility by the established academic surgical community. His only research support from 1964 to 1970 was an annual grant from the John A. Hartford Foundation. Kelman never received research support from the National Institutes of Health, and all of his preclinical and clinical research was done while he was a full-time practicing ophthalmologist.

As **Figure 2** illustrates, 25 years passed before Kelman's phacoemulsification became the definitive technique for removing cataracts. The year 1996 was the first in which 97% of all cataract operations in the United States were done by phacoemulsification on an outpatient basis[1]. The steep rise in acceptance of phacoemulsification from 16% in 1985 (ref. 12) to 97% in 1996 (ref. 1) was a result of evolving improvements in surgical techniques and equipment. Better microscopes, phacoemulsification machines, irrigation systems, sutureless incisions and intraocular lenses all contributed to increasing patient safety and visual acuity.

Impact of Kelman's vision: seeing beyond the cataract

In large part because of Kelman's ingenuity, dedication and inspiration, phacoemulsification has become not only the most common but also the most successful surgical procedure in history. Its simplicity has eliminated most of the operative and postoperative complications of cataract removal and has profoundly broadened the number of patients whose eyesight can be restored with heightened quality of life.

Kelman's vision and influence on medicine extend beyond the lens of the eye. Among the first of the minimally invasive surgical techniques, phacoemulsification stimulated the subsequent development of other outpatient 'keyhole' surgeries, including removal of the gall bladder, lumpectomy of the breast and repair of vertebral discs. The Kelman phacoemulsification machine is used by neurosurgeons to dissect tumors from the delicate tissues of the brain and spinal cord in children.

Kelman has received considerable recognition for his legendary contributions to medicine, including every major award in the fields of ophthalmology and cataract surgery. In 1994, his peers named him "Ophthalmologist of the Century." Moreover, in 1992 he was awarded the National Medal of Technology by President George H. Bush, and in 2004 he was inducted into the National Inventors Hall of Fame, the elite members of which include the likes of Alexander Graham Bell, Orville Wright, Henry Ford, Enrico Fermi and Leo Szilard.

1. Leaming, D.V. Practice styles and preferences of ASCRS members—2003 survey. *J. Cataract Refract. Surg.* **30**, 892–900 (2004).
2. Jaffe, N.S. *Cataract Surgery and Its Complications* 120–122 (C.V. Mosby Co., St. Louis, 1972).
3. Apple, D.J. & Sims, J. Harold Ridley and the invention of the intraocular lens. *Surv. Ophthal.* **40**, 279–292 (1996).
4. Kelman, C.D. Phaco-emulsification and aspiration. A new technique of cataract removal. *Am. J. Ophthalmol.* **64**, 23–35 (1967).
5. Kelman, C.D. The history and development of phacoemulsification. *Int. Opthalmol. Clin.* **34**, 1–12 (1994).
6. Kelman, C.D. History of phacoemulsification. in *Phacoemulsification—New Technology and Clinical Application* (ed. Fine, I.H.) 1–16 (Slack Inc., Thorofare, New Jersey, USA, 1996).
7. Solomon, R. & Donnenfeld, E.D. Recent advances and future frontiers in treating age-related cataracts. *JAMA* **290**, 248–251 (2003).
8. Kelman, C.D. Through My Eyes: The Story of a Surgeon Who Dared to Take on the Medical World 107–110 (Crown Publishing, New York, 1985).
9. Kelman, C.D. Phaco-emulsification and aspiration. A progress report. *Am. J. Ophthalmol.* **67**, 464–477 (1969).
10. Kelman, C.D. Phaco-emulsification and aspiration. A report of 500 consecutive cases. *Am. J. Ophthalmol.* **75**, 764–768 (1973).
11. Kratz, R. From von Graefe to Kelman. A timeline of ophthalmic advances in the 20th century. *Cataract Refract. Surg. Today* **3**, 55–56 (2004).
12. Leaming, D.V. Practice styles and preferences of ASCRS members—1985 survey. *J. Cataract Refract. Surg.* **12**, 380–384 (1986).

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