How I See the Wrist

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Significant contributions to the field of hand or wrist surgery come from only a few ventures into the unknown—discovery of anatomic, physiologic, or biomechanical facts; development of unique surgical procedures that help resolve common wrist ailments; invention of devices that prove advantageous to surgeons or patients dealing with problematic wrist pathology; or establishment of organizations that serve the discipline of hand surgery in lasting ways that exceed the capabilities of individuals alone.

Many hand surgeons have made such contributions. Sterling Bunnell is probably the greatest among them, as his landmark 1944 book *Surgery of the Hand* presaged the establishment of the American Society for Surgery of the Hand. To recite the countless names of wrist surgeons who have advanced this discipline would be pedantic and exclusive. Quite surely, not to use a cliché, I stand on the shoulders of these giants. My contribution to this field was in *how I see the wrist*: through an arthroscope.

A biomechanically complex and intricate evolution of anatomy, the wrist, unlike any other human joint, mimics orthogonal movement without the simplicity of a ball and socket. Eight bones in the carpus mounted on the radius and ulna and a great number of constraining ligaments permit these degrees of freedom and, simultaneously, the stability for load bearing. Amazing!

Arnold K. Henry's *Extensile Exposure*,[1] first printed in 1957 and last printed in 1970, was long the bible for surgical access to various parts of the anatomy, including the wrist and hand. An Irish wit, Henry wrote in his Preface to the second edition, " 'It's all very interesting,' said the Miller's cat to the Mill race, 'but if you could manage to do your work—whose value I don't in the least dispute—a little more soberly, I for one should be grateful.'" Since my first year as a resident in orthopedic surgery at Duke, I was captivated by the views of anatomy through an arthroscope. "A little more soberly," indeed, why should not the advantages of extensile exposure of the wrist be gained with an arthroscope?

And here is how it unfolded. . . .

The wrist I had learned about at the knees of experts: Leonard Goldner, James Urbaniak, James Dobyns, Ronald Linscheid, Julio Taleisniak, and others. But it was only a secondary interest. Arthroscopic surgery of the knee had my focus. As a resident, seeing the floating movements of structures and synovial fragments in a fluid medium, the grace, illumination and magnification of their detail in the knee, had inspired early work on the development of techniques to excise torn portions of menisci under arthroscopic visualization through accessory portals.[2] I developed task-specific instruments for cutting cartilage and clearing the visual field, among them the manual suction punch and a motorized shaver patterned after the vitrectomy device used for removing blood clots after retinal hemorrhages at the Duke Eye Center.

In Richmond, wrist procedures were performed after physical diagnosis and X-ray studies, frequently being uncertain of the mechanical significance of pathologies such as radiocarpal arthrosis, triangular fibrocartilage complex (TFCC) disruptions, scapholunate instability, and carpometacarpal (CMC) arthrosis. Even articular fractures of the distal radius had such a variety of patterns and irregularity that their prognoses were often speculative, at best. Computed tomography (CT) scans at that time were still just two-dimensional film images, and fluoroscopy was both expensive and inconvenient. We needed to examine the wrist internally more thoroughly without incurring the recuperation, rehabilitation, and scarification of a wrist arthrotomy, wherever on the wrist it might be located. Besides, once the complex ligament structures were incised and disrupted, the mechanical significance of an intraarticular lesion could only be inferred.

Trust Your Imagination. Arthroscopic examination of the wrist had been first attempted futilely with cadavers by Burman in New York in 1932.[3] Distension of the joint with inflation pressure, as in the knee, caused fluid extravasation; arthroscopes were too big for the available space; the joint was unstable during examination; and the procedure was largely frustrating and unrevealing.

Ligaments are plastic tissues. They will elongate under an imposed load. Surgical retraction becomes easier with time. External fixators for wrist fractures had proven to place traction loads across the wrist joint that, over time, caused the ligaments to lose their traction effect through elongation and permit reduced fractures to collapse. These experiences meant that joints could be stretched. Why not increase the

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space for wrist joint arthroscopy with traction instead of distension?

Finger trap traction approximately equal to the weight of the arm proved sufficient to distract the wrist joint in just a few moments to admit a 2.5-mm diameter scope. The examination could be conducted with the forearm suspended vertically instead of on an arm table . . . the orientation in which we are accustomed to viewing wrist radiographs in North America. (I still don't know when this changed from the inverted European custom.) This arrangement also stabilized the wrist for examination. Lower, passive fluid pressures would reduce extravasation.

Rod lens arthroscopes could be made smaller. Pediatric cystoscopes were available for our trials in the wrist but proved too fragile due to their length. Richard Wolf Endoscopy in Illinois agreed to fabricate a 2.5-mm diameter arthroscope with a 30° oblique lens in a 3-inch (7.6-cm) length for trial.

Where to introduce the arthroscope into the wrist? The earlier techniques had used the anatomic snuffbox between the first and third extensor compartments. But the curvature of the proximal carpal row prevented visualization of the ulnar aspect of the wrist from this vantage. It was quickly evident that I could not get everywhere in the wrist with a straight arthroscope from a single entry portal. I worked out a system to avoid major nerves and vessels between the various tendon compartments for the radiocarpal space and named these portals for the extensor compartments between which they lay. Later for the midcarpal space, two portals were sufficient and were dubbed the radial and ulnar midcarpal, or RMC and UMC (or midcarpal radial and ulnar, MCR and MCU) portals (►**Fig. 1**).

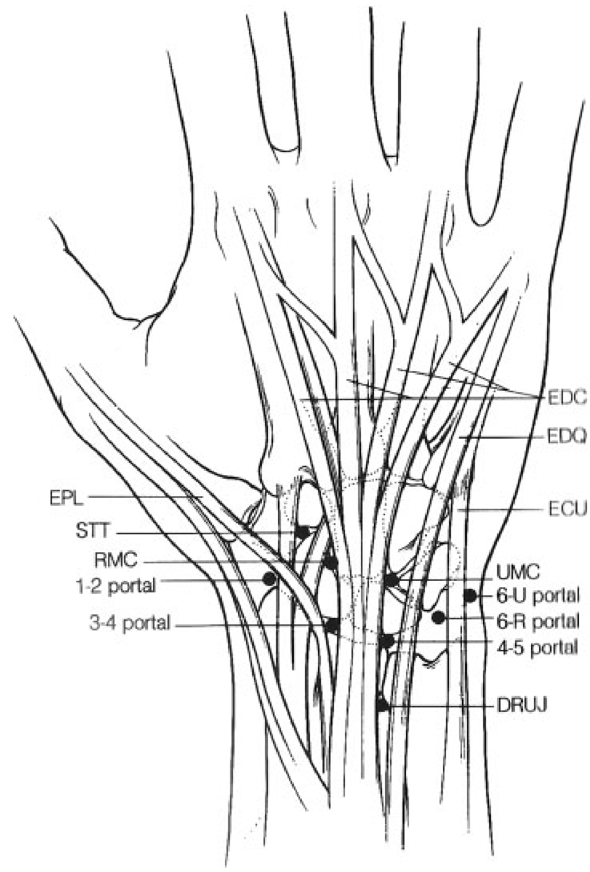

Fig. 1 Diagram of arthroscopy portals located between extensor tendon compartments. DRUJ, distal radioulnar joint; ECU, extensor carpi ulnaris; EDC, extensor digitorum communis; EDQ, extensor digiti quinti (or mimimi); EPL, extensor pollicis longus; RMC, radial midcarpal portal; STT, scaphotrapeziotrapezoid; UMC, ulnar midcarpal portal.

Needing help, I drafted one of our Orthopedic Research of Virginia (ORV) sports medicine fellows, Dr. Jack Powell, in 1984, to work with me for innumerable trials with these visualization techniques in cadaveric extremity specimens. We mapped nearly the entire interior of the radiocarpal and midcarpal spaces with coordinated entries to permit visualization and instrument access to virtually any intraarticular structure and surface.

Clinical trials followed, with patient permission, to visualize their wrist pathology prior to performing a routine arthrotomy. Then still a rookie with only five years of practice experience, I dared to confide what I was working on to a friend and admired mentor, hand surgeon Dr. Don Ferlic, at a function in the home of Professor Frank Bassett, who had supported and encouraged my early ventures with knee arthroscopy at Duke. "Why would anyone want to put an arthroscope in the wrist?" Dr. Ferlic asked . . . or admonished. Undaunted, Dr. Powell and I pressed on.

After nearly a year of clinical trials I called Dr. Gary Poehling at Bowman Gray School of Medicine at Wake Forest. Dr. Poehling had brought the first Watanabe arthroscope (with an exposed, incandescent bulb) from his navy tour in Japan to Duke. He had shown me my first look into the knee through a scope. He was a friend and a confidant. I invited him to Richmond to see the clinical pictures we had taken through our Wolf "wrist scope." He marveled.

After Dr. Poehling's trials back at Wake Forest with a similar Wolf wrist scope, the procedure seemed viable.

Believe in possibility. In Salzburg, Austria, on May 10, 1985, Dr. James Roth from Canada, a clever sports medicine surgeon and a former hand Fellow at Duke, joined Dr. Poehling and me for dinner at the Winkler Hotel during a meeting of the International Society of the Knee (ISK) to discuss the wrist arthroscopy experience and its implications. This, we later considered, was the inaugural meeting of wrist arthroscopists. In London, Dr. Roth also undertook trials with the new wrist arthroscopy techniques.

Dr. Poehling, Dr. Roth, and I timidly staged an introduction of this wrist arthroscopy technique to invited wrist surgeons across the country. We billed the meeting as The Carpal Connection. To our amazement, the invited experts accepted. In February 1986, at the Reynolds Center at Wake Forest University, wrist arthroscopy was televised to an audience for the first time. During the demonstration, one of the guests, Dr. William Bowers, asked whether the distal radioulnar joint (DRUJ) could also be visualized arthroscopically (►**Fig. 2**). This was the smallest and most confined space to access in the wrist, but with a cooperative cadaver specimen, the scope fell easily into place to examine the proximal surface of the TFCC

Fig. 2 Photo of the attendees at the Wrist Arthroscopy Workshop, January 30, 1988. The Bowman Gray School of Medicine, Winston-Salem, NC.

and the contours of the ulnar head and sigmoid notch (►**Fig. 3**).

In teams, the surgeons attending the meeting each tried the technique on cadaver specimens in a makeshift laboratory setting.

Dr. Poehling, Dr. Roth, and I were sports medicine surgeons, all with an interest in hand surgery. We pondered whether wrist arthroscopy would or should become a procedure practiced by sports medicine arthroscopists or by hand surgeon microscopists. Dr. Andy Palmer declared it should be the province of hand surgery and encouraged its dissemination through the ranks of hand surgeons. Dr. Palmer had had personal experience with a few frustrating and largely unsuccessful attempts at arthroscopic visualization of the wrist prior to the new technique. He was an enthusiastic advocate. My feeling was permissive: show the techniques to everyone openly and let those who can use it to their advantage adopt it. A year later, an open meeting of The Carpal Connection was repeated at Disney World in Orlando, Florida. The event was fully subscribed and sold out.

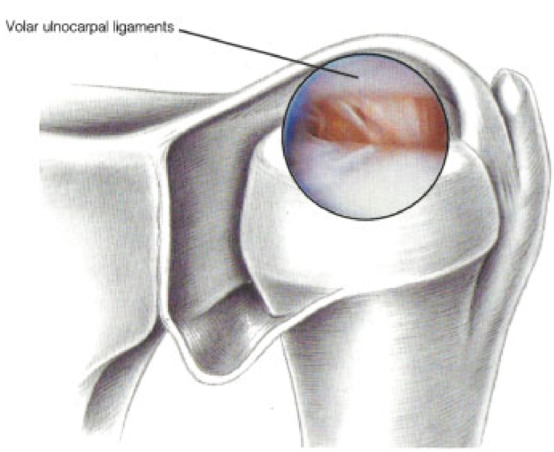

Fig. 3 A view of the proximal surface of the triangular fibrocartilage articular disk in the DRUJ. Note the origin of the ulnotriquetral ligament in the background.

As with the knee and later the shoulder, task-specific surgical instruments soon became necessary for wrist arthroscopy. I appealed to several instrument companies and found Concept Corporation in Largo, Florida, most enthusiastic. Jim Treace, Barry Bays, and Glen Coleman at Concept made numerous trips to Richmond to detail our conceptual modifications for miniaturization of select instrument designs, as well as a few new designs I had sketched.

Traditional wire finger traps were hard on elderly and especially on rheumatoid skin. Larger skin surface area could be used for the same applied traction force by making finger traps from closely woven nylon, allowing the use of less force per square centimeter than wire traps. Specially configured arthroscopic knife blades were designed for specific angles of approach to the TFCC. Intraarticular suturing devices were conceived for arthroscopically assisted suture repairs. A smaller, articulated, sterile traction tower was designed to facilitate limited room in the operating theater and accommodate the sterile surgical field (►**Fig. 4**). This soon was used to facilitate distal radius and metacarpal fracture reductions. Even the suction punch was miniaturized, along with several powered shaver blades and new, more efficient, aggressive designs.

In 1992 I published a textbook titled *Arthroscopic Surgery: The Wrist* with J. B. Lippincott in Philadelphia.[4] Medical

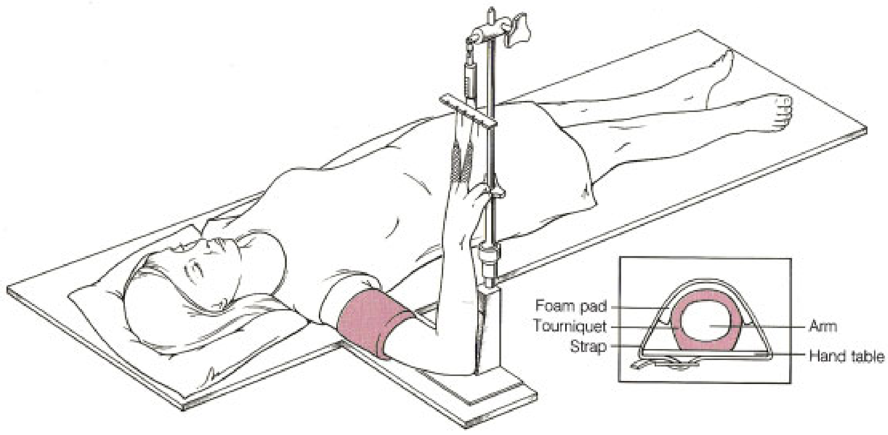

Fig. 4 The patient is supine on the operating table with the shoulder abducted 60° to 90° and resting on a narrow hand table. A restraining strap encircles the tourniquet and hand table (inset).

illustrator Susan Brust deserves superlative compliments for illustrating this textbook, incorporating arthroscopic surgical photography into line drawings for perspective. The first printing sold out.

Seize opportunities. The American Academy of Orthopaedic Surgeons, at its annual meetings, offers a variety of instructional course lectures on topics of deeper, select interest to surgeons. In 1987 I approached the Academy with a proposal for an instructional course on wrist arthroscopy. The Annual Meeting Program Committee accepted. For years, the course was updated and offered at the annual meeting and was fully subscribed. With the excellent and expert assistance of wrist surgeons such as Dr. Richard Berger from the Mayo Clinic, Dr. Lee Osterman of Thomas Jefferson University and the Philadelphia Hand Center, and other esteemed wrist surgeons, this course grew.

Ultimately the Arthroscopy Association of North America proposed that we stage courses at the new Orthopaedic Learning Center in Chicago. These continue to be a part of the surgical skills laboratories at the Learning Center.

The American Society for Surgery of the Hand also offered hands-on courses to teach the diagnostic and surgical procedures that were proving increasingly effective to surgeons treating intraarticular distal radius fractures, TFCC tears, and carpal instabilities. Wrist ganglia were resected from the inside out. Roth and Poehling reported the patient benefits of employing arthroscopic techniques to resect damaged portions of the TFCC, carpal bones, the radial styloid, or the distal ulna in an article published in *Arthroscopy* in 1990.[5]

Task specific instruments. Fractures of the carpal scaphoid had long been problematic because of the bone's precarious arterial circulation. The high incidence of nonunion and postfracture arthrosis had led to an increasing interest in open reduction and internal fixation of scaphoid fractures. Timothy Herbert, MD, from Sydney, Australia, developed a unique, headless fixation screw for the scaphoid, with variably pitched threads at either end for fracture compression.[6] With proven advantages to using this Herbert screw for internal fixation of the scaphoid, couldn't this be done arthroscopically?

Again, the challenge was simplifying the procedure and the several instruments and steps necessary for proper placement of the Herbert screw into the scaphoid with fracture compression. The screw had to be redesigned. It was possible to visualize scaphoid fracture lines in the scaphoid arthroscopically through the midcarpal space. A new screw was cannulated with an increased diameter of the unthreaded segment so it could be introduced over a smooth Kirschner wire (K-wire) that could be passed percutaneously across the fracture. Self-tapping threads with a more aggressive pitch were added to reduce the number of steps for the procedure and to increase fracture compression

Fig. 5a, b (**a**) After drilling over the primary guide wire, an appropriate length Herbert-Whipple cannulated screw is introduced through the guide barrel, transfixing the scaphoid fracture. Compression is maintained by the jig, and rotation is prevented by the secondary wire. (**b**) Screw placement 2 weeks postoperatively.

forces. A new guide was designed to facilitate arthroscopic placement, compression, and measurement of screw length. The Herbert-Whipple screw would now be capable of simpler, arthroscopic fracture fixation of this problematic bone (►**Fig. 5a, b**).

We then began injecting established scaphoid nonunions and delayed unions with centrifuge-concentrated bone marrow aspirate under arthroscopic and fluoroscopic guidance after fracture stabilization with the Herbert-Whipple screw. This attempt at bone grafting fractures with a particulate marrow "slurry" introduced the necessary osteoblast cells, but possibly, unwittingly, also introduced stem cells of marrow origin into the fracture site. Most of these injected fractures progressed to mature bony union.

Dr. Paul Feldon had devised a "wafer" procedure for treating ulna impaction syndrome by resecting 2–4 mm of the distal head of the ulna.[7] I treated such a patient with this procedure by resecting the wafer arthroscopically with an aggressive milling burr. The patient also had a central tear of the TFCC that was resected. I was surprised to find on reexamining the wrist arthroscopically 8 weeks later that the central defect in the TFCC had filled in with a remodeling cartilaginous patch from the hematoma that had developed from the ulna shortening. Was it possible to use blood patches to repair cartilage defects? Believe in possibility.

By this time, all but the most complex wrist surgical procedures could be performed without resorting to an arthrotomy—without disrupting the soft tissues of the wrist, without prolonged immobilization or soft tissue rehabilitation, without large, permanent incision scars. International wrist surgeons from Germany, France, the Netherlands, Great Britain, Italy, Argentina, Japan, China, and other countries joined the visitor list from around the United States coming to Richmond to observe and train. Dr. Didier Fontes staged the first European surgical education course devoted specifically to arthroscopic techniques for the wrist in Nice, France, in May 1996.

Our Sports Medicine Fellowship at ORV in Richmond was modified to recruit applicants with specific interest in the wrist as well as sports medicine. Dr. Will Geissler was one of the most prolific of these Fellows in 1990–1991. Dr. Geissler has since devised techniques for categorizing or grading the severity of carpal instabilities arthroscopically,[8] as well as techniques for precisely reassembling the articular surface of distal radius fractures under arthroscopic visualization.

Dr. P. C. Ho from The Chinese University of Hong Kong developed techniques for using bone graft paste for osteoinduction of carpal fusions performed arthroscopically.[9] Drs. Christophe Mathoulin, Toshiyasu Nakamura, Riccardo Luchetti, and Francisco del Pinal added significant refinements to techniques for employing arthroscopy for examination and treatment of both common and uncommon disorders of the wrist. The list of experts and surgical innovators is too extensive to recognize the contributions that have been made by each in the use of wrist joint arthroscopy since 2000. With my apologies for this limitation, suffice it to say that logic in wrist physiology and biomechanics has inspired the creative bravado of many surgical innovators to expand the horizons of this minimally invasive and advantageous surgical technique.

On March 19, 2005, Prof. Christophe Mathoulin of Paris established the first official organization dedicated to minimally invasive, arthroscopically facilitated surgery of the wrist. The European Wrist Arthroscopy Society (EWAS) has since become a premier international association of wrist surgeons focused on unselfish dissemination of education in arthroscopic surgery and consultation for problematic wrist cases. EWAS has staged practical courses to teach surgical competence with arthroscopic techniques throughout the world, reaching surgeons on five continents.

The future of wrist arthroscopy is limited only by the imaginations of surgeons and engineers. New advances in medical technology has been cataclysmic. Many of these new technologies are adaptable to minimally invasive surgical techniques. Their effects on tissue physiology are being documented convincingly. The adaptation of scientific discovery and development to surgical treatment techniques is to be encouraged.

It is conceivable that future wrist arthroscopy developments will hinge essentially on parallel developments in visualization and imaging, in physiology, in tissue engineering and molecular biology, and in the concept of "minimally invasive."

Visualization. At the risk of sounding much like science fiction in a medical science journal, optical resolution through flexible glass fibers is improving to the point that small internal fibers may adequately display internal anatomic structures without the use of the larger rod lens arthroscopes in conventional use today. Such optical fibers may be introduced through hypodermic needles, even as an office procedure, more economically and less uncomfortably than arthroscopy performed in surgical suites.

Indirect imaging is becoming possible with miniaturized ultrasound echo sensors. Similarly, electromagnetic sensors using radiofrequency probes have the capacity to create imaging of intraarticular structures in ways that could replace direct visualization. Conceivably, such probes may even become indwelling sensors to monitor active motion testing during joint movements. With rapid advances in magnetic resonance technology, it is not inconceivable that we will one day see and use much smaller magnet coils incorporated into wrist splints to provide cine magnetic resonance (CMR) imaging for real-time, noninvasive examination of wrist structures.

Tissue engineering. All anatomic structures in the wrist are composed of connective tissue, a mixture of collagen and elastin. Bone, cartilage, ligaments, and tendons are differential derivatives of the same common stem cell precursor. Thus, stem cells are rapidly becoming the implant of choice for tissue replacement or regeneration in all joints, including the wrist. Pending developments in tissue engineering will assist in modulating the differentiation of stem cells into different mature cell types and replacement tissues. As a prelude to these events, we have already observed by serendipity the advantages of stem cell grafting for TFCC regeneration and accelerated healing of fracture nonunions, as previously mentioned.

Physiology. Integrating biophysics with arthroscopy has enormous future therapeutic patient advantages, especially for the wrist. Temporarily heating connective tissue cells (fibroblasts) to 60°C will increase their expression of heat shock proteins (HSPs). These proteins can initiate inflammatory responses and additional cell recruitment to produce new collagen along old tissue substrates. If, under arthroscopic control, damaged tissues can be focally or regionally heated to that temperature threshold, it may be possible to thicken and strengthen wrist ligaments, whether damaged or not. This would constitute a new treatment approach to common wrist sprains and lesser symptomatic incidences of carpal instability.

Minimally invasive spectrum. Consider, then, the concept of “minimally invasive” arthroscopic surgery for the wrist. We have all observed and experienced the evolution of Henry’s extensile surgical exposure into minimally invasive surgical procedures. The advantages to patients undergoing and recuperating or rehabilitating from these less invasive procedures is obvious. With the advent of better fiber optics, pixel enhancement, echo sensors, and pinpoint laser biomodulators, all potentially introducible into the wrist through needles—even radiolucent needles made of carbon composite materials—minimally invasive surgery will evolve into microinvasive surgery.

This concept is hardly imaginary. Miniaturization is already operational in the communications and electronics industries today. Circuit boards can are being built on pinhead-sized chips. Why should it not apply in surgery for the wrist . . . and other anatomic regions, with the wrist, perhaps, being the pilot? Circuitry and other industry capabilities must be adapted and refined for medical use.

Future wrist surgeons. That said, as the technologies supporting these new procedures evolve, so, too, will the surgeon of the future need to change. Our surgical skills reside in our minds as well as our hands. Consider the following invasive or “surgical” procedures performed today, every day, deftly and successfully, by nonsurgeons. Myelograms and kyphoplasties are performed by interventional radiologists; neural rhizotomies are performed by physiatrists; coronary artery stents and cardiac valve replacements are installed by interventional cardiologists. Even the earliest French arthroscopists were rheumatologists such as Dr. Henri Dorfman, not surgeons.

Wrist surgeons tomorrow will be precision tissue scientists, not the battlefield amputation doctors of yesteryear. As robotics replace a surgeon’s hands, and as needles replace arthroscopic portals, so will microinvasive surgery be replaced by noninvasive surgery. Trust your imagination.

Noninvasive surgery is graphically illustrated by the evolution of the gamma knife. This gamma ray device uses powerful and finely focused ionizing radiation to remove or kill intracranial tumors without the need for a craniotomy. The gamma technology is not new to surgery. It was actually developed in 1951 by Dr. Leksell in Stockholm, Sweden—over half a century ago. Other forms of electromagnetic radiation and other energy sources are under development or refinement for evoking biological effects. Indeed, it has become possible to surgically address deep anatomic tissues or structures transparently to the skin without the need for surgical incisions or even punctures. Noninvasive surgery is the conceptual result of surgical minds applied to biophysics and engineering.

It would seem opportune, at this juncture, to close with a triplet I have come to cherish since my earliest foray into surgical research and development. Encouraged by surprising early laboratory (and business) successes—and probably then still in a state of euphoria—I composed this in 1975. It has guided me ever since. I would commend it to all of us sharing the curiosity and fascination with surgical skills in a joint as complex and mechanically sophisticated as the wrist.

- Trust your imagination.
- Believe in possibility.
- Seize opportunities.

These concepts have been referenced rhroughout this article, perhaps not obviously at the time of first reading. Together, however, they underlie nearly every new venture undertaken and mastered by surgeons through the years. They constitute guiding principles for success in any endeavor, surgical or not, and are anchors with which we can persevere in the continued advancement of medical and surgical science.

This, in a nutshell, is *How I See the Wrist.*

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