

The Evolution of Laparoscopy and the Revolution in Surgery in the Decade of the 1990s

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INTRODUCTION

"Incredibly, laparoscopy has been almost neglected by surgeons, except for pelviscopy, a highly perfected technique used effectively by gynecologists. This procedure has, in fact, revolutionized the science of gynecology. The degree to which we as surgeons ignore this sophisticated technology and refuse to test its suitability for surgical application is astonishing." These were the words of Hans Troidl in his presidential address at the International Congress on Surgical Endoscopy, Ultrasound and Interventional Techniques in Berlin, 1988.¹ By using the word, "revolutionized," Dr. Troidl was ignoring almost a century of evolution in endoscopy and another 80 years in laparoscopy.

The changes in surgical endoscopy leading up to 1988 were, in fact, gradual and evolutionary. For any major change or progress to take place, many factors must fall into place. In the case of laparoscopy, dramatic technical innovations were required. Additionally, there is a season for any change, requiring a favorable and supportive philosophical environment. Authoritative institutions must be convinced of the safety and efficacy of the changes relative to the comfortable status quo. Momentum always favors inertia. Fears must be overcome: fear of making mistakes, fear of failure, fear of established procedures becoming obsolete, and fear of established authorities losing control. Successful change requires timing and a force more powerful than the status quo. The strongest force for sustainable change is a worthy goal.

THE EVOLUTION OF LAPAROSCOPY

Phillip Bozzini is credited with developing the first cystoscope, although it was never used in humans. In 1805, he developed an awkward system of candles and mirrors to examine canine bladders.¹⁻³ During the 19th century, lenses, light sources, and endoscopes evolved, and surgeons and internists performed cystoscopy, proctoscopy,

laryngoscopy, and esophagogastrosopy.³ In 1901, German surgeon George Kelling used a cystoscope through the abdominal wall to evaluate the effect of pneumoperitoneum in dogs, inventing the technique of "celioscopy."¹⁻⁵ After enduring harsh criticisms from the medical community, he later applied his technique to humans, publishing his results in 1910. Swedish surgeon Hans Christian Jacobaeus is credited with coining the term "laparoscopy" ("laparothorakoskopie").⁴ He began his animal experiments in 1901, inserting cystoscopes without pneumoperitoneum.⁴ He subsequently reported his clinical experience with 17 laparoscopies using pneumoperitoneum, and 2 thoracoscopies in 1910. He also was subjected to criticism.⁶

THE EVOLUTION OF LAPAROSCOPIC SURGERY

As Dr. Troidl indicated in his 1988 presidential address, general surgeons lost interest in laparoscopy during the early 20th century, but gastroenterologists, internists, and gynecologists recognized its inherent value. A German gastroenterologist, Heinz Kalk, developed a superior laparoscope with improved lenses and the first forward-viewing scope in 1929, earning him the title "Father of Modern Laparoscopy."² Kalk pioneered in many diagnostic techniques, including a safe technique for laparoscopic liver biopsy.

In the 1930s, internist John Ruddock popularized laparoscopy in the United States. Using a forward-viewing scope similar to Kalk's, he extolled the virtues of diagnostic laparoscopy as a safer, less-invasive alternative to laparotomy.² The goal of minimally invasive surgery (MIS) was clearly identified. In 1933, gynecologist Karl Fervers described laparoscopic lysis of adhesions using cautery.^{3,4,7} Three years later, Boesch, a Swiss gynecologist, performed the first laparoscopic sterilization by electrocoagulation of the fallopian tubes.^{2,3,7} These breakthroughs paved the way for operative laparoscopy, but progress was very slow. By 1971, 35 years after Boesch's breakthrough, only 1% of sterilizations in the United States were performed laparoscopically by surgeons like Dr. Karl Levinson, a former Society of Laparoendoscopic Surgeons (SLS) president. By 1976, however, 60% of tubal ligations were laparoscopic.^{2,7} The pace of laparoscopic evolution

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was picking up. The evolution of laparoscopy from its origin with George Kelling in 1901 to a therapeutic modality for Fervers and Boesch took one-third of a century. It took another 40 years to reach 1% penetration, and laparoscopy stalled at the level of bilateral tubal ligation for a full 40 years. Moreover, Bozzini's invention of the cystoscope laid the foundation for laparoscopy a full century before the first transabdominal "celioscopy" was performed by Kelling. The development of laparoscopic surgery was clearly a gradual evolution and not a revolution.

The early slow pace of endoscopic and laparoscopic evolution was in large part related to the limitations of technology. It was further slowed by skepticism of the medical and surgical communities. The early laparoscopic surgeons experienced many examples of repression by the old guard of traditional surgery.

During the mid-1950s to 1970s, further concerns were raised about a significant increase in complication rates due to bowel injuries and cautery injuries for women undergoing laparoscopic sterilization. Laparoscopic surgery was effectively banned in Germany from 1956 to 1961.² In the 1970s, similar concerns were raised in the United States, in addition to concerns about higher pregnancy rates following the laparoscopic techniques. Although laparoscopy was becoming recognized as an important element of gynecologic training programs, only limited procedures were taught. Textbooks in the 1970s and 1980s emphasized diagnostic laparoscopy and ovarian cyst aspirations, but not ovarian cystectomy or operative laparoscopy.^{2,4} The environment was definitely not conducive to rapid change. It has been said that change is a little like heaven; everyone wants to go there, but no one wants to be there.⁸ The 1970s and early 1980s were not the season for change.

During the mid-1960s and 1970s, gynecologist Kurt Semm in Kiel, Germany, contributed greatly to laparoscopic technology. He perfected many technical refinements, including an automated insufflator, the suction irrigator, safer electrocoagulation instruments, intracorporeal and extracorporeal knot tying, and an electrical morcellator for myomas.^{2,4} In 1971, gynecologist and SLS past president Harrith Hasson contributed to the safety of laparoscopy, developing the Hasson trocar with the open entry technique. In 1983, Kurt Semm performed the first laparoscopic appendectomy, bringing him criticism and censor rather than accolades. The German Board of Surgery condemned him.^{2,9,10} The first surgeon to perform a laparoscopic cholecystectomy met with a similar fate. German surgeon Erich Muhe used his "galloscope," a 3-cm, direct-

vision laparoscope of his own design to remove a gallbladder. He presented his work at the 1986 Congress of the German Surgical Society. He, too, suffered skepticism and criticism and was ultimately censored by the courts.^{2,3} The season for change had not yet arrived.

VIDEO LAPAROSCOPY

Although the technology was improving, thanks in large part to Kurt Semm, the critical advance was still missing. The single most important technological advancement for complex laparoscopic surgery would be the advent of video laparoscopy. Video technology was developing in the 1960s and was being touted for teaching purposes and documentation, but the resolution was not sufficient for operative laparoscopy.^{2,11} As late as 1977, Berci was still advocating video technology for teaching and documentation only.^{2,12} A fledgling gynecology resident in Buffalo, New York, however, had the vision to couple a video camera to his laparoscopic eyepiece and work from a monitor. In his SLS presidential address in 2005, Dr. Camran Nezhat described with considerable humor his early efforts suspending an unwieldy camera from the ceiling with duct tape and squinting at a low-resolution image on his monitor.¹³ Encouraged by his mentors and supported by industry, he ultimately developed a video system adequate for surgery after much work during the late 1970s and early 1980s. He also endured criticism and ridicule, but succeeded in developing a multidisciplinary team that was able to work in concert from video monitors. Nezhat and his team performed many complex operations for the first time, but his papers were refused by established journals for years and, like Muhe and Semm, he was rewarded only with criticism, and ultimately a formal investigation, following which he was fully exonerated.² Machiavelli's often-quoted phrase "There is nothing so difficult or so dangerous as to change the order of things"⁸ still applied to the surgical environment of the 1980s.

During the early to mid-1980s, videoscopic images were applied to endoscopy and ultimately to the laparoscope. The technology was now in place to support multiple people working in concert by laparoscopy. The term "minimally invasive surgery" was coined by English urologist Mr. John Wicker, who established a department of minimally invasive surgery at the Institute for Urological Surgery in 1983.⁶

In 1987, French surgeon Phillip Mouret performed the first videolaparoscopic cholecystectomy and, like Muhe, Semm, and Nezhat, was strongly criticized. Francois Dubois, another Frenchman, was the second surgeon to

perform videolaparoscopic cholecystectomy in 1988 and was the first to publish his early experience.¹⁴ General surgeon Barry McKernon and gynecologist William Saye in Marietta, Georgia, were the first to perform laparoscopic cholecystectomy in the United States. Shortly thereafter, Eddie Reddick and Douglas Olsen (another SLS past president) published the first United States series, and the evolutionary phase of laparoscopic surgery came to an end.

What followed can only be described as a revolution in general surgery, as well as urology and gynecology. Laparoscopic cholecystectomy was introduced to the general surgery world in the exhibit hall of the American College of Surgeons annual meeting in October 1989. Courses were organized by Reddick, Saye, and Olsen and soon by other pioneers in the field, proliferating to meet the frenzied demand from general surgeons worldwide. With no scientific evidence to support or justify the change from open to laparoscopic gallbladder surgery, the change did, in fact, occur almost overnight. Patients were demanding the new surgery, and instrument companies were supporting courses and even paying tuitions for surgeons to be trained to use their products.

THE REVOLUTION BEGINS

Academic surgeons, such as Cuschieri, Berci, and McSherry, called for a moratorium on the new surgery, arguing that the procedure should be evaluated and validated first in specialized centers.¹⁵ Quite to the contrary, in many areas, laparoscopic cholecystectomy began in private practice and later migrated to academic centers. Thomas Dent summarized this unstoppable tide writing, "there is no organization with enough authority to prevent surgeons from performing these procedures, even if such restriction were desirable."¹⁶ The season for change had clearly arrived! The media helped to fan the excitement, and patients, once informed, were demanding the new surgery. The environment was now favorable for minimally invasive surgery. The technology, especially videolaparoscopy, had evolved, and instrument companies were working furiously to keep up with demand and to develop instruments to facilitate the new operation. But a revolution would be anemic at best if only one operation were to be affected. Laparoscopic appendectomy, first performed by Semm in 1982, published in 1983 and seconded by Phillip Mouret in 1983, became commonplace by the early 1990s.

The surgical community was being swept by a tidal wave of enthusiasm in minimally invasive surgery and a thirst

for information about new applications, instrumentation, and techniques. To harness this enthusiasm and organize and proliferate this information, the Society of Laparoscopic Surgeons (SLS) evolved under the leadership and direction of Dr. Paul Wetter, Janice Chinnock, and a multidisciplinary team of dedicated surgeons. Recognizing the value of cross-pollination of knowledge and skills among the surgical specialties, the organization embraced the philosophy of inclusiveness and collegiality, escaping the pedantic atmosphere of some established societies. SLS was incorporated in 1990 as an educational, nonprofit organization to help ensure the highest standards for the practice of endoscopic and minimally invasive surgery, and committed to providing its members access to the newest responsible ideas and innovations as rapidly as possible. Throughout the decade of the 90s, and since, SLS has been a forum for innovation and progress in our field. The *Journal of the Society of Laparoendoscopic Surgeons*, thanks to the tireless work of Dr. Michael Kavic (past president of SLS) and Patricia Kavic, has become the most widely distributed minimally invasive surgery (MIS) journal in print.

During that first year of the laparoscopic explosion, Leonard Schulz and John Corbitt developed several approaches to laparoscopic herniorrhaphy.^{1,2} Drs. Joseph Petelin (a past SLS president), and Reddick and Olsen developed laparoscopic common bile duct exploration. In 1991, Camran Nezhat et al reported a partial colectomy, and DB Redwine, Dennis Fowler, and Moise Jacobs performed laparoscopic segmental colon resection.¹⁶⁻¹⁹ The same year, Namir Katkuda, Bernard Dallemagne, and Zucker and Bailey began laparoscopic vagotomy for peptic ulcer disease, and Philip Mouret performed laparoscopic repair of a perforated ulcer.^{1,2,9,20,21} Urology was also affected as laparoscopic pelvic node dissection for carcinoma of the prostate was popularized by American surgeon John Flowers and French urologist Tierney.^{1,22,23} Dr. Ralph Clayman in the United States and N. Ferry in France performed laparoscopic nephrectomy.^{1,2,24} Gynecologic laparoscopy also experienced dramatic progress from 1989 to 1992. Laparoscopic hysterectomy was developed by Drs. Camran Nezhat and Harry Reich (both past presidents of SLS) and S. Kovac and G. Magi.^{2,25-27} Laparoscopic radical hysterectomy with aortic and pelvic lymph node dissection followed, led by Drs. Joel Childress, Camran Nezhat, and Farr Nezhat (3 past presidents of SLS) and French gynecologist Dargent.^{2,28,29}

Over the next few years, virtually every abdominal operation was performed and perfected by laparoscopic technique. Laparoscopic splenectomy was performed by

Mokoto Hashizume, Ed Phillips, Joe Petelin, and John Flowers,^{30,31} and adrenalectomy by Petelin and Gagner.³² Even pancreaticoduodenectomy was introduced by Gagner. As the decade of the 90s was waning, laparoscopic radical prostatectomy was described by Clayman in the United States and Vallancien in France.³³ By 1997, fully laparoscopic aortofemoral bypass was being performed, led by Dion and Gracia.³⁴

VASCULAR SURGERY

Vascular surgery was revolutionized by minimally invasive techniques on many fronts during the decade of the 90s. With the development of reliable endovascular materials, percutaneous transluminal angioplasty (PTA) began in the early 1990s. Endoluminal stents for occlusive disease and for aortic aneurysm repair followed.^{35,36} Laparoscopically assisted aortofemoral bypass with mini-laparotomy was first described by Dion in 1993,³⁷ and in 1995 Chen reported the first laparoscopically assisted abdominal aortic aneurysm repair.³⁸ Later in the decade, totally laparoscopic aortic surgery was performed in a handful of centers.³⁹⁻⁴² Although operative times for laparoscopic vascular surgery improved with repetition, the learning curve was steep. Also, endovascular stenting had developed a firm hold on the treatment of vascular disease in the United States and in much of the world. Surgery was relegated to endovascular failures and to pathology unsuitable for stenting. Many centers abandoned their laparoscopic aortoiliac surgery programs because of low volume. Thus, the season for change to laparoscopic surgery for vascular disease had passed. Nonetheless, vascular surgery was revolutionized by minimally invasive endovascular techniques during the decade of the 90s.

The first robot-assisted aortofemoral bypass was performed by Zimmerman and Kelley in 2000.³⁶ Although vascular surgeons felt enabled to perform aortic anastomoses comfortably with robotic assistance, this procedure also failed to proliferate in the United States and in many other countries for the same reasons that traditional laparoscopic aortic surgery failed to take hold. In contrast to the United States environment, however, some countries lagged behind in the penetration of endovascular surgery due to the expense of that technology. In the Czech Republic, Petr Stadler performed 116 robot-assisted major vascular procedures from November 2005 to July 2008 (personal communication from Dr. Stadler). In his country, robot-assisted aortic surgery has caught on as an MIS alternative with reduced reintervention rates and costs compared with those of endovascular procedures. In the Czech Republic, the season for change in laparoscopic

vascular surgery was favorable, thanks to the seeds that were sown in vascular and robotic surgery in the 90s.

BREAST SURGERY

Breast surgery also underwent dramatic minimally invasive changes during the 1990s. At the beginning of the decade, surgical biopsy of suspicious breast lumps and mammogram findings comprised one of the most frequent operations performed by general surgeons. In 1991, Steve Parker published the first series of stereotactic large-core needle biopsies for suspicious mammographic findings.^{43,44} The sensitivity of this procedure was 96%. Subsequent recognition of the occult cancer risk for needle biopsy diagnosis of atypical hyperplasia raised the sensitivity to 98% and higher.^{45,46} As experience grew with ultrasound-guided biopsy, reliable tissue diagnosis was established for solid mammogram lesions and for palpable lesions as well.^{47,48} During the decade of the 90s, an office ultrasound machine became at least as important as a stethoscope for general surgeons interested in breast care. Open surgical breast biopsy had largely disappeared by the end of the decade.

During the mid-1990s, stereotactic biopsy devices became more robust. Vacuum-assisted 11- and 14-gauge biopsy needles sampled more tissue, resulting in improvements in specificity and sensitivity, further reducing the need for open surgical biopsy.^{45,49} Subsequently, a stereotactic excisional biopsy device was produced that removed 10-, 15-, or 20-mm diameter, intact, cylindrical specimens through a limited incision.^{45,50,51} This type of device is felt to have potential as a therapeutic device as well.

Breast cancer therapy experienced similar dramatic changes during the decade of the 90s. Prior to the mid-1990s, most patients with infiltrating adenocarcinoma underwent axillary lymphadenectomy, exposing them to risks of lymphedema, neuralgias, and infection liability in the upper extremity. Most of the physiologic impact of breast cancer surgery resulted from the axillary dissections. The technique of sentinel lymph node biopsy revolutionized breast cancer treatment by dramatically reducing the need for axillary dissection for most breast cancer patients. Giuliano⁵² first applied lymphatic mapping technology to breast cancer patients in 1994, using isosulfan blue dye. Krag et al⁵³ subsequently reported sentinel lymph node biopsy guided by a technetium sulfa colloid, detected by a Gamma probe. Cox et al⁵⁴ later published the best yield for sentinel lymph node detection using both dye and isotope, identifying the sentinel node in 94% of patients. The false-negative rate for sentinel lymph

node biopsy is no higher than 4%, so patients with negative sentinel lymph nodes are spared axillary lymph node dissection.⁵⁵ Therapeutic lumpectomy, arguably minimally invasive breast surgery, was also enhanced by image-guided breast biopsy during the 90s. The incidence of re-excision for positive margins following lumpectomy was reduced.⁴⁵ In a single-institution study, the need for a second operation for patients diagnosed by core needle biopsy was 16% versus 71% for patients diagnosed by open surgical biopsy.⁵⁶

ROBOTIC SURGERY

Robotic surgery is considered by many to be one of the next evolutions in minimally invasive surgery. The first robotic system for laparoscopic surgery became available in 1994. Aesop (formerly Computer Motion, Santa Barbara, CA) directed the laparoscope following the surgeon's voice command. Zeus, a fully integrated surgical system, became available for investigational use in the United States in 1996. Dr. Tamaso Falcone performed the first United States procedure, a robot-assisted tubal re-anastomosis.² The da Vinci robotic surgical system (Intuitive Surgical, Sunnyvale, CA) was introduced in Europe in 1997. Dr. Guy Cadere did the first procedure, a robot-assisted laparoscopic cholecystectomy in Brussels. Da Vinci became the first United States FDA-approved integrated robotic surgical system in July 2000, following which Kelley and Owens performed the first procedure. It is now the only commercially available robotic system for laparoscopic and thoracoscopic use.

The most critical value of robotic technology lies in its enabling capabilities, allowing surgeons to perform complex tasks that would exceed their abilities with traditional laparoscopic instrumentation. Cardiac surgeons who had never used video-laparoscopic techniques are now doing single-vessel coronary artery bypass grafts and mitral valve repair and replacement by robot-assisted, minimally invasive surgery.⁵⁷⁻⁵⁹ The fastest areas of growth have been radical prostatectomy and complex gynecological surgeries, enabling urologists and gynecologists to perform procedures that were previously being done only by the most experienced laparoscopic specialists in their respective fields. Over half of radical prostatectomies are now being performed by robot-assisted laparoscopic surgery.

The season for change was right for robotics in urology, gynecology, and cardiac surgery. Although that season had already passed in general surgery, where most procedures were being performed laparoscopically by the majority of interested surgeons, the potential remains for

future robotic systems and applications, such as robot-assisted natural orifice transluminal endoscopic surgery (NOTES) and independent mini- and micro-robots to make incremental improvements in surgical outcomes.

FURTHER EVOLUTION OF MIS

The revolution of minimally invasive surgery that permeated virtually all aspects of surgery in the decade of the 90s has subsided. However, the season for change remains favorable. An exciting, though slower-paced evolution is now underway, building on the explosive advances in the 90s. Natural orifice surgery (NOS) was introduced in the 90s with endoscopic instruments for antireflux procedures. The most recent addition for NOS has been the Esophyx (Endogastric Solutions, Redwood City, CA), FDA-approved October 2007, which performs a transoral, full-thickness, 240-degree fundoplication. Single-port access, developed by Drs. Paul Curcillo and Stephanie King, is an incremental extension of the concept of MIS by introducing 3 to 4 trocars through one umbilical incision to perform laparoscopic procedures. Single-port access is currently being evaluated and may prove to be a bridge to NOTES, or a modification of NOTES, using similar instrumentation through a single umbilical incision. It may also be an alternative to NOTES where access to the technology is limited by expense or surgeons' comfort levels. The seeds for NOTES were sown in the 90s with endoscopic transgastric drainage of pancreatic pseudocysts and endoscopic ultrasound-guided transenteric biopsy of pancreatic masses and other retroperitoneal lesions. What has followed has been a measured, even guarded, progress of research and development. The season for rapid change has not yet arrived for NOTES, because technology has not quite caught up with imagination. Now is a time for perspective (separating the very interesting from the very important) and judgment (the time to do vs the time to pause).⁸ A combined American Society for Gastrointestinal Endoscopy (ASGE) and Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) working group on NOTES published a position on measured, step-wise approaches to the development and introduction of this technology to clinical application.^{60,61} Consistent with the origins, mission, and history of our society, SLS must take a synergistic role with these and other societies, educating surgeons about the exciting changes that are developing in this new season of evolution, while fostering perspective and judgment to optimize patient outcomes. As was the case in the 1900s, technology will catch up with imagination and the evolution of minimally invasive surgery will continue.

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