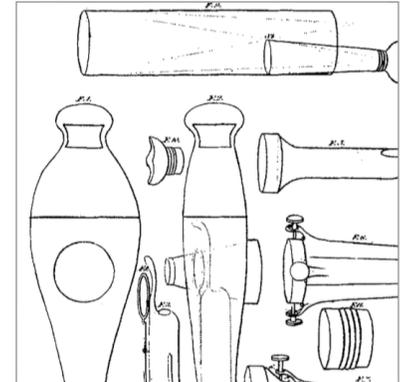


Fig. 4. — Position de l'endoscope pendant l'application.



10

The minimally invasive operations that transformed surgery



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AUTHOR

Don K. Nakayama, MD, MBA

*Department of Surgery, University of North Carolina at
Chapel Hill, Chapel Hill, NC*

CORRESPONDING AUTHOR

Don K. Nakayama, MD, MBA

*170 Manning Drive G196 Physicians' Office
Building Ground Floor, C.B. 7223
Chapel Hill, NC 27599-7223*

The history of minimally invasive surgery (MIS) began with the first cystoscopes in the early 19th century. Endoscopes were essentially cystoscopes applied to other organs and body cavities. Beyond dilation of strictures and biopsies of the lower urinary tracts, the first endoscopic therapeutic intervention was thoracoscopy to free the lung of adhesions during pneumothorax treatment of pulmonary tuberculosis by Hans Jacobeus in Sweden and Germany in 1912.

Laparoscopy was largely a diagnostic procedure performed by a few internists in the 1930s and 1940s, notably by Heinz Kalk in Berlin and John Ruddock in Los Angeles. Gynecologists Raoul Palmer in Paris and Hans Frangenheim in Germany began to use laparoscopy in the diagnosis of gynecological conditions and the evaluation of infertility in the 1940s and 1950s.

Kurt Semm in Munich and Kiel in the 1970s began to actively advance laparoscopic surgical operations: first gynecological procedures, then the first laparoscopic appendectomy in 1980. In 1985, Erich Mühe, a general surgeon in Böblingen, Germany, did the first laparoscopic cholecystectomy. Advances in imaging (Hopkins rod lens system) and illumination (fiber optics) in the 1950s, and imaging (solid state cameras and high definition video displays) in the 1980s, provided video images with sufficient anatomic detail to allow surgical operations of increasing complexity. Technology allowed endoscopy to realize its full potential, a true revolution in surgery.

Pioneers of endoscopy

The ability to look within a body cavity in a living patient was a long held dream in medicine. Until the early 19th century the diagnosis of a patient's malady, unless it was visible or easily palpated, was a secret that the body yielded only at surgery or autopsy, the former procedure associated with death just a little less than the latter.

Phillip Bozzini of Frankfurt had invented the original endoscope in 1806, a leather-lined box that held a candle interposed in the sightline between the examiner's eye and a speculum wedged into the urethra or vagina to inspect for signs of venereal disease, urethral strictures, and bladder stones (Figure 1).¹ In 1883, Antoine Desormeaux of Paris replaced the candle with an alcohol and turpentine-burning lamp. The light was brighter but the contraption became dangerously hot, a problem in a device held so close to the patient's perineum and the examiner's face. Desormeaux replaced Bozzini's unwieldy speculums with a long tube, creating the first true cystoscope (Figure 2). The former's other lasting contribution was the name of his apparatus, which he called "l'endoscopie."² In 1865, Sir Francis Richard Cruise of Dublin was the first to explore a body cavity, the empyema cavity in the thorax of an 11-year-old girl, using a cystoscope of Desormeaux's design that he modified to produce more light.^{3,4}

Georg Kelling (1866-1945) in Germany was the first to examine the abdomen with an endoscope, a procedure that he called "celioscopy." He found that insufflation of the abdomen with air, a procedure that he had tried in an unsuccessful attempt at controlling gastrointestinal hemorrhage, was a good way to create working space within the abdominal cavity. The only documentation of his experience was "a memorable lecture" before the Society of German Natural Scientists and Physicians in 1901 that predicted modern laparoscopy. He said, "[Endoscopic] methods for the intestinal tract may find more use than it has been the case until now, as they are actually qualified to substitute the laparotomy in many cases."⁵ He purportedly performed 45 such procedures to diagnose various lesions and tumors. Tragically, he died at age 79 in the Allied bombing of Dresden in 1945.⁵

Hans Christian Jacobaeus (1879–1937), an academic physician in Sweden who later became head of the department of internal medicine at the Karolinska Institute in 1916 and chair of its Nobel Prize committee, knew the necessity of publication to establish priority.⁶ Despite the work of Cruise and Kelling, Jacobaeus has been called “the inventor of human laparoscopy and thoracoscopy.”⁶ He performed diagnostic laparoscopy on 17 patients with ascites, an experience which he published in 1910. He also examined two patients without ascites, a more difficult technical challenge where injury to the viscera was much higher. He took Kelling’s idea of insufflation of air into the peritoneal cavity to create the distance to inspect intraabdominal structures, and used a trocar with a trap door that kept the air from escaping during the examination. He followed two years later with a second report of 97 patients, including 8 patients without ascites.⁷

In 1912 Jacobaeus began work with Ludolph Brauer at the Hamburg-Eppendorf Hospital in Germany and an advocate of therapeutic pneumothorax in the treatment of tuberculosis.⁷ They used thoracoscopy to free the lung from adhesions that prevented complete atelectasis.⁸ He largely abandoned laparoscopy, likely because the thoracoscopy allowed a therapeutic intervention, whereas the conditions where he used laparoscopy were mostly incurable, such as liver disease and malignancy.⁹

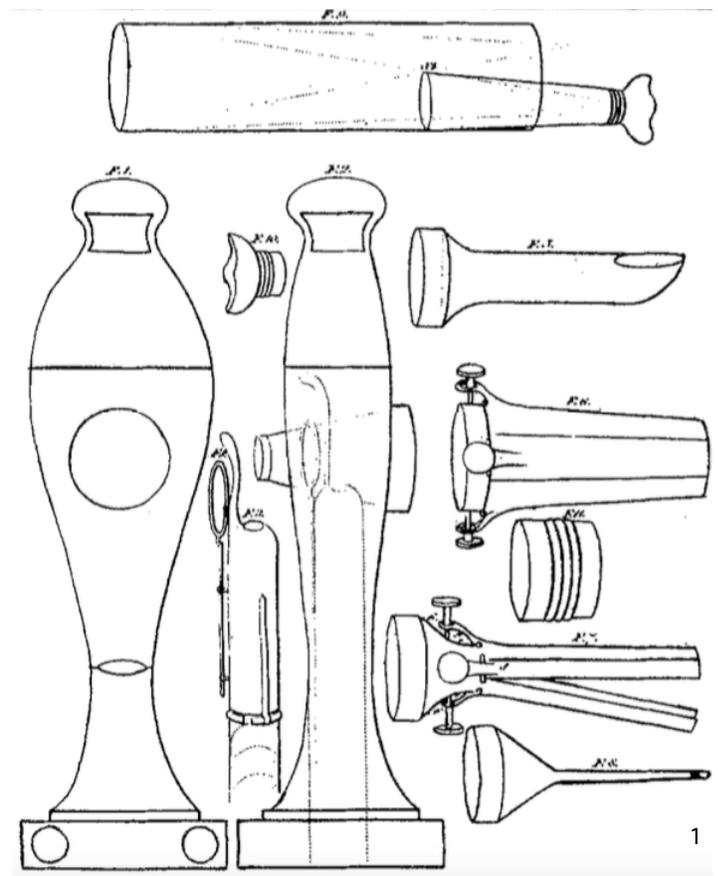
In 1911, one year after Jacobaeus’s report, Bertram Bernheim of Baltimore reported the use of a sigmoidoscope to inspect the interior of the abdomen, a procedure that he called organoscopy. After working the procedure out on dogs at the Hunterian Laboratory at Johns Hopkins, he tried it on two human patients, one on a jaundiced patient with a distended gall bladder from a carcinoma at the head of the pancreas; the other, a patient suspected of a chronic gastric ulcer who had chronic appendicitis.¹⁰ With such modest results, Bernheim’s interests turned to other areas.

Pneumoperitoneum

Pneumoperitoneum was a necessary precedent to the development of laparoscopy. It originally was a radiological procedure to outline the viscera on plain films and fluoroscopy. New Yorkers Arthur Stein, a gynecologist, and William Stewart, a radiologist, introduced the modality in America in 1919. They used an anesthesia bag to inflate the free abdominal cavity with air or oxygen through a standard spinal needle.¹¹ Two years later, Walter Alvarez, an internist in San Francisco, reported the use of carbon dioxide for the procedure. The peritoneal cavity absorbed carbon dioxide within a few minutes, a distinct advantage over oxygen or air, which sometimes remained in the abdomen over days with prolonged discomfort.¹²

Benjamin Orndoff, the founding chair of the department of radiology at the Stritch College of Medicine at the Loyola University in Chicago, familiar with the diagnostic pneumoperitoneum, tried his hand at laparoscopy and reported his experience in 1921. After inducing the pneumoperitoneum, he also used fluoroscopy to avoid injuring the viscera when he placed a trocar for his scope.^{13,14}

Janos Veres, a Hungarian internist, described his eponymic needle in a 1936 report in the Hungarian literature in a description of inducing pneumothorax for tuberculosis. His invention is familiar to all surgeons performing laparoscopic surgery today: To protect the organs from injury, he placed a spring loaded blunt obturator within a needle. The wall of the chest or abdomen pushed the blunt tipped obturator backward, exposing the sharp edge of the needle and allowing the assembly to penetrate the layers of tissue. When the tip of the needle entered a body cavity, the sudden loss of tissue resistance allowed the obturator to spring forward beyond the end of the needle, where it could protect the underlying viscera from injury. Alfred Cuschieri, one of the leading figures of surgical laparoscopy, speculated that Kurt Semm was one of the first to use the Veres needle in his pioneering work on laparoscopic surgery, which will be described below.¹⁵



Early laparoscopists

Grzegorz Litynski, a historian at the Johann Wolfgang Goethe University in Frankfurt, profiled the key contributors in the history of laparoscopic surgery in a series of articles that appeared in the late 1990s. Several important figures were in France and Germany during years surrounding World War II, a noteworthy commentary on the dedication of clinician-scientists to their work in the midst of unimaginable political upheaval and social disruption. Many of Litynski's references came from the European literature in the authors' native languages, so his articles are an important summary for English-only readers.

Heinz Kalk studied surgery at the Charité Hospital in Berlin after serving in World War I on the Western Front. Because the liver and spleen lay beyond the diagnostic capabilities of gastroscopy and radiology, he became interested in diagnostic laparoscopy. In 1928 he obtained a special endoscope with a 135-degree field of view. He designed a trocar that had a spring device that retracted its sharp point after entry, a principle much like the Veres needle. By 1942 he had performed 750 procedures, including biopsies of the spleen (which he first did in 1934), and liver (in 1935, reporting 123 biopsies in 1943). He was in the medical services of the Luftwaffe in World War II, where he put his device to use in performing diagnostic laparoscopies on soldiers suffering from epidemic hepatitis.¹⁶

On the American side, John Ruddock in Los Angeles had done more than 2,500 laparoscopic cases and taken 1,000 biopsies between wars in the 1930s and 1940s.¹⁷ In 1949 he reported a diagnostic accuracy of nearly 94 percent.¹⁸ Ruddock, like Kalk, had served in the armed forces in both wars. Contemporaries and pioneers in the same field, they faced impossible barriers of language, geography, politics, and ultimately armed conflict.¹⁶

Kalk and Ruddock's enthusiasm for the procedure was not generally held, especially among surgeons. It made little sense to perform laparoscopy under general anesthesia simply for diagnosis, when one could do a definitive operation through a standard incision.¹⁶ A survey of internists and surgeons taken in 1966 documented that less than 10 percent had done a diagnostic laparoscopic procedure, and fewer than one percent had done more than 50. "After a brief stir," wrote Litynski, "most surgeons abandoned peritoneoscopy because of its limited therapeutic applications."¹⁶

Gynecologic laparoscopy

Gynecologists were the first specialists to fully devote themselves to laparoscopy and its therapeutic potential. Raoul Palmer, a gynecologist at the Hôpital Broca in Paris, and his wife Elizabeth started to perform laparoscopic procedures in occupied Paris in 1943. As the war drew to a close everything became scarce, from household items to hospital supplies. Raoul recognized the importance of controlling the amount of pressure within the abdomen, so he added a manometer to his insufflator, which he jury rigged from parts he found in storage areas in his hospital. Unable to drive to nearby towns because of gasoline rationing, he rode his bicycle to scrounge the carbonic acid necessary to generate carbon dioxide gas. Surgical gloves were in short supply, so the Palmers rinsed their hands repeatedly with an alcohol solution during their procedures.¹⁹

The Palmers first used cystoscopes outfitted with incandescent bulbs the size of a corn kernel. Attached to a 4.5 V flashlight battery outfitted with a rheostat, they often burned out during examinations. Despite the challenges of wartime, in 1947 Palmer reported an experience of 250 "coelioscopies gynécologiques"¹⁹ that included descriptions of his instrumentation and examination techniques, "the most substantial published work on the application of laparoscopy in women's medicine at the time."¹⁹

The miniature light bulbs barely gave enough light to examine the pelvic organs, much less photography. In 1952 a Parisian optical firm used quartz rods to transfer light from a 150 V lamp outside the body. Despite its shortcomings – the lamp was "searingly hot," it needed a cooling system so noisy that it made normal conversation impossible, and the quartz rods were fragile and broke easily – it was the most effective means of illumination until fiber optic cold light systems became available in the 1960s.¹⁹ Called proximal illumination, it provided enough light for photography; the Palmers even made an 8 mm color movie of a procedure in 1955.

Added to his expertise in infertility, laparoscopy made Raoul Palmer a leading international figure in gynecology. "Literally hundreds of physicians from all over the world came to the Parisian 'temple' of gynecology [the Hôpital Broca where he practiced]," said Litynski.¹⁹

Postwar America favored culdoscopy, inspection of the pelvis through the posterior fornix of the vagina, largely through the efforts of its primary proponent, Albert Decker, a gynecologist in New York.²⁰ He saw the posterior fornix as a potential access point for endoscopy, long used as a point of access for needle aspiration of the pelvic cul-de-sac to detect a collection of blood or pus, or a convenient place to begin mobilizing the uterus during vaginal hysterectomy.²¹

To create a pneumoperitoneum Decker insufflated the abdominal cavity through the cervix, gas passing into the peritoneal cavity through the uterine cavity and the Fallopian tubes. It was an established gynecological procedure, called the Rubin test, to confirm patency of the Fallopian tubes in the evaluation of infertility. (Shoulder pain from gas irritating the undersurface of the diaphragm confirmed patency of the tubes and a positive test.) Once the abdomen was thus distended, sturdy assistants held the patient in a knee-chest position as he made a small incision in the posterior fornix for an endoscopic examination of the pelvis.²²

Hans Frangenheim was alongside the Palmers as the foremost figures in gynecological laparoscopy in postwar Europe. After service in the German air force during the war he was assigned work in an American hospital in Allied-occupied Germany. There he completed surgery and gynecological training and found a job in Wuppertal at a women's clinic.²⁰

Frangenheim tried culdoscopy but found it cumbersome and inadequate in visualizing the pelvic organs. After study of Kalk's papers, he decided an anterior approach would give simple access to the pelvic organs without the difficult position that culdoscopy required. When he visited the Palmers in Paris in 1955, he saw the Palmer's insufflator and recognized it to be far superior to hand injection by syringe and needle. He made his own device in 1959, a modified anesthesia machine that pumped carbon dioxide into the abdomen. Like Jacobaeus earlier in the century, Frangenheim established his position in the field through his publications, including the first textbook on gynecological laparoscopy in 1959.²⁰

Kurt Semm and operative laparoscopy

Kurt Semm, a German gynecologist, was the first to begin to perform laparoscopic operations beyond lysis of lung adhesions and biopsies of tumors and solid organs. A member of Nazi youth groups and a member of the Nazi army, he was captured by the Russians at war's end. Upon his release he returned to Munich, where he studied medicine and gynecology at the university and stayed on faculty at its women's clinic.

Among his duties was the Rubin test. Like Decker, Semm saw that it created enough space for laparoscopy, but chose instead to have the patient in the supine position. Semm, an inveterate tinkerer who invented toys to make ends meet in the immediate aftermath of the war, built his own insufflator in the mid-1960s with salvaged tools and parts. Later both the Palmers and Frangenheim accused Semm of stealing their designs.²³

His chief of service, Richard Fikentscher, opposed his foray into laparoscopy, so Semm convinced a colleague at another hospital, Herbert Schwiegk, give his insufflator a trial run. Schwiegk was "overjoyed" with the device and began to use it for all of his procedures.²³ As Semm's luck would have it, Schwiegk happened to mention to Fikentscher how pleased he was with the device. The boss was not pleased. "I was called into his office, where he was shouting incredibly loud," said Senn.²³ Fikentscher relented after a visitor from Argentina happened to observe a laparoscopic procedure on one of Fikentscher's patients. "Brilliant!" the visitor said, "Gentlemen, I tell you brilliant!"²³

In 1967 Semm took his device to a conference in Washington, DC, where he met Melvin Cohen, a Chicago obstetrician who was interested in laparoscopy and culdoscopy. The American directed Semm to his technician, a German Jew who had escaped to the U.S. during the war. The former Nazi soldier and the Jewish refugee overcame their anathema to each other and agreed to work together to test the device. Cohen was pleased with its performance. American Cystoscope Makers, Inc. (the company that worked with Basil Hirschowitz to create the first marketable flexible endoscope in 1961),²⁴ recognized immediately the potential value of the insufflator. Before long hundreds of his devices were being used in America.²³

Semm moved to Kiel and began work on laparoscopic surgical operations. Palmer had used laparoscopy to cauterize Fallopian tubes for ablation in 1962. Now in the 1970s, Semm began to use laparoscopy to address a wider array of tubal, ovarian, and uterine pathology.²⁵ He took each part of a surgical operation—cutting, suturing, tying knots, creating exposure—and invented the corresponding shears, needle holders, clamps, forceps, and retractors on the ends of long handles that allowed their manipulation from outside the body. Instruments were placed through fixed ports, a concept Semm popularized. He had an advantage: His father and brother owned WISAP, a medical instrument company. They were thus able “to [produce] the devices Semm wanted “almost overnight,” wrote Litynski.²⁶

He used a loop of suture with a slip knot already in place, called a Roeder knot, for his tubal ligations, ovariectomies (placing the entire structure within the loop then cinching it closed), and control of bleeding vessels.²⁷ He became adept at tying knots, both outside (extracorporeal) and inside the body (intracorporeal).²⁶ His work during the 1970s created many of the instruments and basic procedures of modern laparoscopic surgery.

In 1979 he reported his experience of 3,300 pelviscopies, which included myomectomy, ovariectomy, ovarian cyst resection, adnexectomy, and treatment of tubal pregnancy.²⁸ When the paper appeared, in Litynski’s words, “[a] true storm broke loose.”²⁶ Many disbelieved the total number of cases. Traditionalists remained unconvinced of the concept of laparoscopy. Its supporters, notably the Palmers and Frangenheim, contended that Semm emphasized only the technical performance of laparoscopic procedures without proving their safety or efficacy, such as lysis of Fallopian tube adhesions for infertility. His articles prominently featured the instruments he and his family designed, especially his diathermy device and insufflation systems. “What impressive numbers, and how little they tell us,” Frangenheim wrote in 1979.²⁶

Semm was undeterred. It was undeniably a revolutionary way to perform surgery. “Those ... who witnessed him in action,” Litynski wrote, “spoke of ‘the magician of Kiel.’”²⁶ In February 1980 one medical periodical in Germany wrote, “When will the first appendix or gallbladder disappear into an endoscope?”²⁶ The writer did not have to wait long. Just months later in September, Semm performed the first laparoscopic appendectomy.^{29,30} Later that decade in 1985 Erich Mühe, a general surgeon in Böblingen, Germany, and in 1987, Philippe Mouret, a gynecologist in Lyon, did the first laparoscopic cholecystectomies.^{31,32}

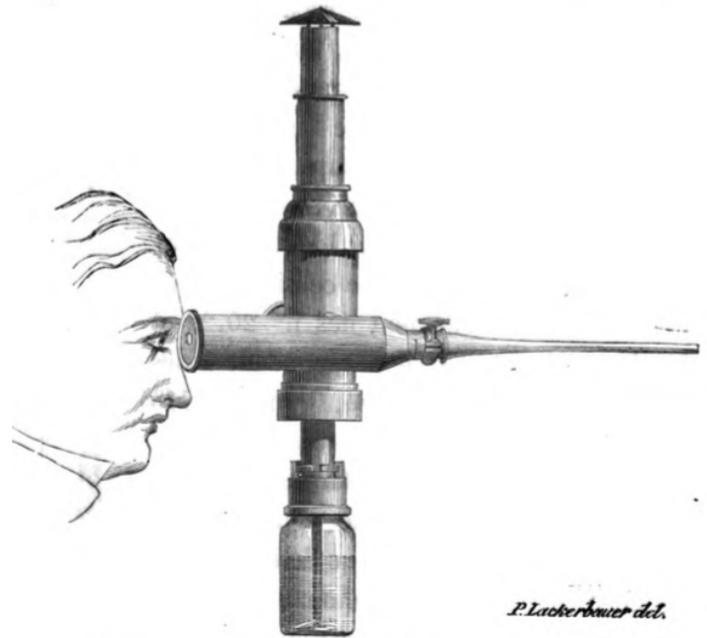


Fig. 4. — Position de l'endoscope pendant l'application.

2

A technological revolution in surgery

The future of laparoscopic surgery had to expand beyond the small number of gynecologists with a special interest in laparoscopy and into general surgical practices. Mouret did his two-and-a-half-hour cholecystectomy on his side lying on the patient’s right thigh to keep his eye over the objective of the scope. “[It] had been a contortionist’s exploit,” he said. For laparoscopic surgery to be adopted, it simply had to be made easier to perform.³²

Thus two technological advancements in imaging and illumination in the 1950s were key improvements in the development of therapeutic laparoscopy. The Hopkins glass rod-lens, developed by Harold Hopkins in the late 1950s, produced images 80 times better than the Galilean optics that had been used in traditional cystoscopes.³³

Fiber optics originated in the same decade with papers published back-to-back in *Nature* in 1954 by Hopkins and Narinder Karpany at the University College in London and their rival, Abraham van Heel, at the University of Delft. Lawrence Curtiss at the University of Michigan made a key improvement by cladding each fiber with glass of a lower refractive index, which prevented the loss of light by assuring internal reflection along the length of the light-carrying fiber.³⁴

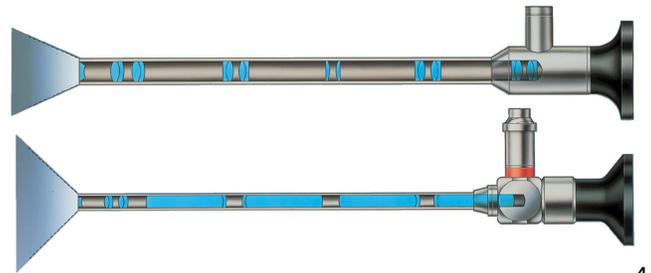
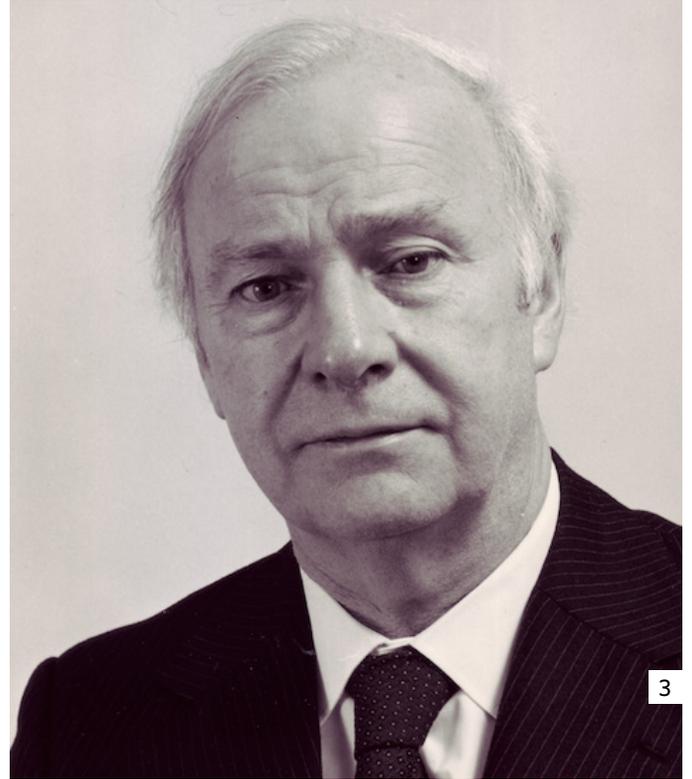
Fiber optics made two fundamental technological contributions to medicine: flexible endoscopy and proximal illumination. The former revolutionized the practice of gastroenterology; the latter provided the light needed for laparoscopic surgery. The principle was the same as the Palmer's arrangement with a high voltage light source outside the body, but now illuminated glass fibers placed on the rim of the endoscope brought light inside the body, and thus replaced the Palmers' unwieldy quartz rods.³⁴

The final step was solid state camera technology of the 1980s that created the first wave of electronic digital cameras and portable video systems.³⁵ As video monitors improved the images on high definition displays, surgeons had the optical resolution they needed to discern the anatomic detail necessary to perform surgical operations of increasing complexity. Their eye no longer locked onto the objective of the laparoscope held by one hand, surgeons could stand, view the operation on a video display, and perform standard operations using both hands.

Surgery was thus transformed in the latter half of the 1980s. Arnold Pier and Friedrich Götz, two surgeons from Linnich, a town near Cologne, started to do laparoscopy for all of their cases of appendicitis. Their experience, 678 cases in a little over three years from 1987-1990, was reported in 1991. They had to abandon laparoscopy to perform an open operation in only 14 cases (2%).³⁶ By March 1987 Mühe had already accumulated 97 cases of video-laparoscopic cholecystectomy; in April 1989 Dubois reported 36 laparoscopic cases, of which three were converted to an open procedure.³¹ In the months between submission of his article and the appearance of the publication in proof, he had added another 220 cases to his experience, with the last 180 done without complications.³⁷

The procedure spread to France and the U.S. by Francois Dubois of Paris, Jacques Perissat of Bordeaux, J. Barry McKernan and William Saye of Marietta, GA, and Eddie Joe Reddick and Douglas Olsen in Nashville, TN. In 1989 tremendous interest was generated by presentations by Perissat at the Society of American Gastrointestinal and Endoscopic Surgeons in Louisville in April, and by Reddick and Olsen at the American College of Surgeons in Atlanta in October. Classes offered in the U.S. quickly became oversubscribed.³¹

Laparoscopy spread to other operations and other specialties. For patients the benefits were undeniable, with smaller, less painful incisions and faster recovery. Instrumentation improved, especially stapling devices that could be deployed through laparoscopic incisions. By the 1990s nearly all operations in every major surgical specialty could be done using laparoscopy and minimally invasive techniques, a true revolution in surgery.



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Legends

- 1 Bozzini's Lichteiter. Diagram from Bozzini P. Lichteiter, eine Erfindung zur Anschauung innerer Theile und Krankheiten nebst der Abbildung. *Journal der practischen Arzneykunde und Wundarzneykunst* (Berlin). 1806;24:107-124.
- 2 Desormeaux's *l'endoscopie*. Illustration from Reference 2.
- 3 Harold Hopkins. Photo courtesy Karl Storz Endoscopy (UK).
- 4 Hopkins rod lens system. Figure courtesy Karl Storz Endoscopy (UK). Top: cross section of a scope with glass lenses placed at intervals, separated by air-filled spaces. Bottom: Hopkins rod lens system, with solid glass rods separated by lens-shaped intervals of air.