Endometrial Ablation: Past, Present and Future Part I

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ABSTRACT

Endometrial ablation (EA) is a commonly performed minimally invasive technique to manage intractable uterine bleeding that is unresponsive to medical therapy. It originated in ancient times when chemical astringents were used to control uterine hemorrhage associated with childbirth and a variety of other gynecologic conditions. In the late 19th century the use of astringents and chemical cauterants gave way to the application of a variety of thermal energy technologies to cause selective destruction of the endometrium. These energy sources—steam, electricity and even gamma rays—were applied blindly and were, by all accounts quite effective at a time when hysterectomy was unsafe, infrequent, and generally unavailable.

With the emergence of improved optics and laser and video technology in the late 20th century, a resurgence of interest in endometrial ablation began—coinciding with a time when hysterectomy was commonly performed in developed countries. Endometrial ablation underwent a revolutionary change as physicians searched for new techniques to perform selective endometrial destruction under direct visual—hysteroscopic—control. In this first of a two-part series, we will explore the first and second generations of endometrial ablation to understand how this procedure has evolved into its present status and what issues remain to be solved.

ENDOMETRIAL ABLATION: PAST, PRESENT, AND FUTURE

Precursors to endometrial ablation: astringents

Endometrial ablation (EA)—the selective destruction of the endometrium—was developed to control intractable uterine bleeding. This method likely originates from the ancient use of astringents, such as chemical compounds that cause contraction of mucous membranes. In the 2nd century Soranus of Ephesus[1] wrote an authoritative text, *Gynecology,* in which he describes uterine hemorrhage as a potentially "grievous calamity." In his remarkable treatise, the Greek physician advised that uterine hemorrhage might be controlled with the intrauterine insertion of "plasters made of dates soaked in tart wine or in vinegar, together with a cerate of roses or of quinces…or with alum…or bloom of the wild vine." Other "plasters" were "made with some astringent and cooling herb (like purslane, henbane, plantain, fleawort, black nightshade, *perdikion*, knotgrass, endive) together with barley powder and vinegar or dates."

The application of astringents to control uterine hemorrhage continued for many centuries. In 1872 Ludlam[2] reported the use of "strong alum water" and noted that "the temptation to resort to astringents, topically and internally, in case of hemorrhage, is a very strong one. This is especially true in those forms of uterine haemorrhage which are connected with menstruation." In 1889. Thomas Ashby[3] wrote of a colleague that:

> …had never met with a case of menorrhagia or metrorrhagia in which the hemorrhage could not be controlled for the time being by the use of the curette or with mild astringent applications of the endometrium… He had found mild applications of the persulphate of iron exceedingly serviceable in uterine hemorrhage. He protested against the employment of fuming nitric acid to the endometrium and would not apply a solution of nitrate of silver stronger than 20 grams to the ounce.

In 1910, McKee[4] reviewed several methods of endometrial "cauterization" including the use of "chemicals"—astringents. He noted that "cauterization to the point of destruction of the endometrium, especially in cases of severe hemorrhage, was formerly extensively practiced." He also reported that "these strong cauterants often destroyed the endometrium beyond the possibility of regeneration and left the inner lining of the uterus nothing but a mass of scar tissue." Although McKee favored the practice of *curettement* over cauterization, he noted that "if curettement is not permitted, cauterization is then the next best thing. This may be done by chemicals, electricity, and of late years by steam." Eventually the complications associated with the use of astringents—inadvertent chemical burns—caused it to fall into disfavor. Nonetheless, physicians would continue to explore other minimally invasive modalities to control intractable uterine bleeding.

FIRST GENERATION ENDOMETRIAL ABLATION: THE BLIND DESTRUCTION OF THE ENDOMETRIUM

Unlike chemical cauterization of the endometrium, nearly all modern EA techniques involve the application of thermal energy to selectively destroy it. Many of these techniques originated in the late 19th century when surgical and anesthetic techniques were rudimentary, crude, and risky. In 1882, even in the hands of such eminent surgeons as Spencer Wells of St. Mary's Hospital in London, hysterectomy-related mortality regularly exceeded 70%.[5] In this setting, the search for a safe, minimally invasive, convenient, and inexpensive alternative for the control of obdurate uterine bleeding was both important and desirable.

To accomplish endometrial ablation, as we recognize it today, a succession of energy sources was applied as they became available, manageable, and

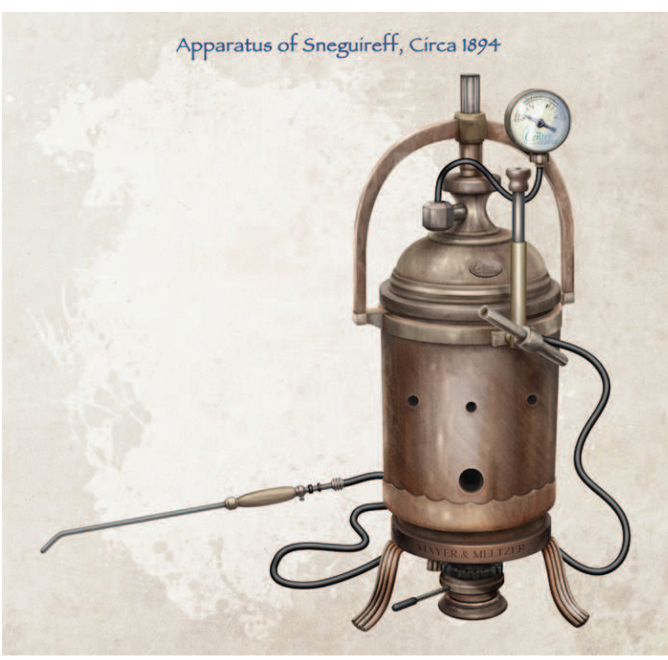


Figure 1. Sneguireff's device for endometrial vaporization.

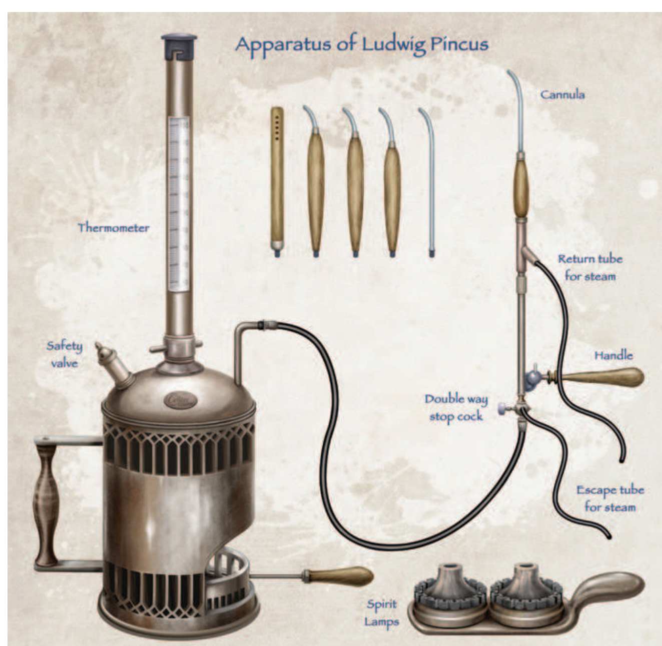


Figure 2. Pincus' device for endometrial vaporization.

understood. The earliest medical accounts began with the application of steam—the energy source that powered the industrial revolution. As other sources became available—electrical, radium, laser—they each enjoyed an opportunity to advance the safety, efficacy, economy, and convenience of endometrial ablation techniques.

The history of endometrial ablation has been poorly understood within our specialty. In 2002, Franklin Loffer[6] noted that "endometrial ablation was probably first described in 1937 using an electrical method. No further work was done until 1971 when endometrial destruction was attempted by cryotherapy." In a more recent textbook edited by Bradley and Falcone,[7] there is no mention of any endometrial ablation performed prior to the introduction of the neodymium-doped yttrium aluminum garnet (Nd:YAG) laser (1981). As a result, the techniques of Nd:YAG and "rollerball" endometrial ablation are generally mischaracterized as "first-generation techniques"—a moniker that disavows over a century of endometrial ablation history. An analysis of endometrial ablation modalities reveals accounts of this innovative approach documented in late 19th century in an attempt to offer this minimally invasive technique to women for the management of otherwise uncontrollable uterine bleeding.

Atmocausis (superheated steam)

In 1886, Professor Sneguireff of Moscow[8] published his first account of the successful application of superheated steam to the interior of the uterus—known as *atmocausis*. The observation, by Simpson,[9] that "vaporisation of the endometrium has an action at once caustic, haemostatic, anaesthetic and antiseptic" laid the foundation for what a century later would become known as endometrial ablation. Professor Sneguireff's device, according to Simpson,[10] consisted of a kettle for generating the steam and a double catheter for conveying "the hot vapour into and out of the uterine cavity." The inner tube carried steam into the endometrial cavity while the outer one allowed it to egress.

Professor Sneguireff's landmark work soon inspired Dr. Ludwig Pincus of Danzig[11,12]—who, according to Blacker[13] created many refinements and modifications and offered additional specifics regarding the application of this device for endometrial vaporization. A modernized version of Professor Sneguireff's and Pincus' devices are presented by the author in Figures 1 and 2, respectively. In addition to these improvements, Pincus was able to describe many specifics regarding his device's utilization that were omitted in Sneguireff's early report. By the end of 1895, Dr. Pincus[12] had performed endometrial vaporization "in a few cases with good results." Much of what we know of Pincus' first attempts at endometrial vaporization—or atmocausis—was summarized in a review article by Blacker[13] and published in 1902 in *The Journal of Obstetrics and Gynaecology of the British Empire*.

In 1899, Dr. Pincus presented his preliminary findings at the 71st meeting of the Association of German Naturalists and Physicians (Munich, Germany). Pincus, who collaborated with Professors v. Winkel and Fritsch, was able to obtain follow up data on 833 women and reported that 749 were either cured or greatly improved during a relatively short interval of follow-up.[13] The report of this large series greatly influenced the recognition of endometrial ablation over much of Europe and America as an important technique for managing intractable uterine bleeding. According to Blacker,[13] Pincus' apparatus "is more convenient to use than that of Sneguireff, gives more certain results, and entails less danger of scalding either the patient or the operator." The early indications for atmocausis were well-described[8-10] and included "(1) certain forms of preclimacteric hemorrhage; (2) all cases of hemophilia; (3) certain cases of bleeding myomata, and of hemorrhage from inoperable cancer corporis uteri…" as well as others.

Blacker[13] also discussed the appropriate setting for this minimally invasive procedure and noted that "the operation of vaporization of the uterus can be performed without anesthetic." He also commented that "the administration of an anesthetic is, however, preferable in the great majority of cases" allowing it to be "more efficiently performed."

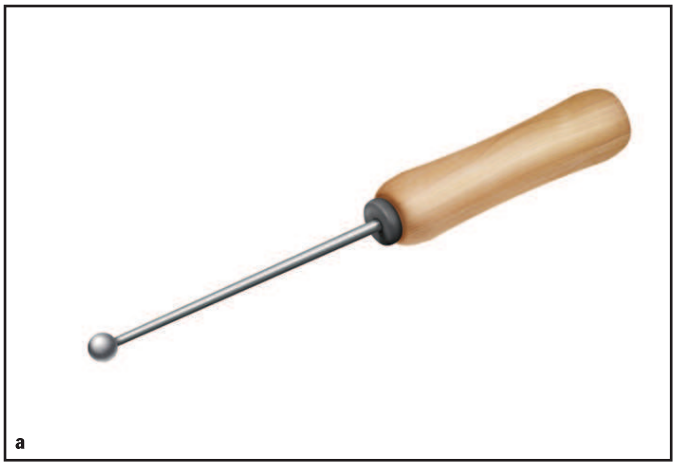
The limitations of atmocausis were also described. In 1907, Howard Kelly[14] commented that "any procedure is objectionable surgically which leaves a sloughing surface." Kelly emphasized that "Practically, it is difficult to perform destructive atmocausis. The difficulty lies in affecting all parts of the endometrial cavity equally. When any part of the mucosa is not entirely destroyed, the endometrium becomes regenerated subsequently at that point. If the cervical canal in such a case has been obliterated, accumulation of menstrual blood and of glandular excretions is sure to follow within the uterus." Kelly concludes that "in general, hysterectomy is preferable to destructive atmocausis" though he suggests that "the lesser degree of atmocausis may be tried in preference to hysterectomy in cases of persistent uterine bleeding, after the failure of curetage." Hirst,[15] who was far more skeptical of the benefits of atmocausis, noted that "the cauterization [of atmocausis] is difficult to regulate, is not entirely safe, predisposes to cervical stenosis or atresia, and may obliterate the uterine cavity." Hirst also reported that two fatalities "had been observed in women who had previously had thrombosis of the pelvic veins."

Hot water

In 1897, Kellogg[16] acknowledges that Schrick of Prague treated four subjects with intractable uterine bleeding by introducing boiling water introduced into the endometrial cavity through a Bozemann-Filtsch catheter while protecting the vagina and vulva with ice-cold water irrigation. Schrick treated subjects for 30 seconds and was able to achieve acceptable results in three of the four subjects. Kellogg reports "…excellent results in cases of this sort by applying water at a temperature of 160° to 180° F to the endometrium by a metal double canula closed at the inner end. A current of hot water passing through the canula heats it, maintains the heat at any temperature desired; and it may be kept in contact with the diseased surfaces for a sufficient length of time to produce any desired effect. It is an excellent measure for stopping hemorrhage and destroying vegetations."

Electrosurgery

The late 19th century also witnessed the development of what would prove to be an indispensable surgical energy course—electricity. Modern surgeons are deeply indebted to Jacques-Arsène d'Arsonval who, in 1888, began studying the effect of alternating current on neuromuscular excitability.[17] D'Arsonval recognized that the application of low-frequency electrical currents to



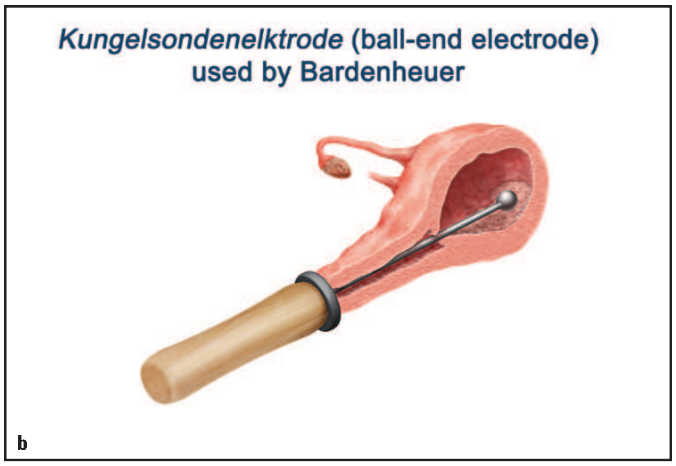


Figure 3a and b. Bardenheuer's Kungelsondenelktrode used in ELK.

human tissue caused muscular contraction—even tetany—and that the intensity of this excitation increased with the frequency up to a maximum of about 5 kHz. Thereafter, muscular contractions decreased until it was barely noticeable at the highest frequency of his machine—about 10 kHz. D'Arsonval also noted that the current density influenced body temperature, oxygen absorption, and carbon dioxide elimination, and, most importantly, that tissue temperature increased proportionately to the square of the current density.[18]

In 1897, Franz Nagelschmidt discovered that patients with articular and circulatory ailments benefited from the thermal effect provided by the application of electrical currents and applied the term *diathermy* to describe it.[19] In 1900, Dr. Joseph Rivere, a Parisian physician, utilized a generator similar to one employed by Nagelschmidt to treat a carcinomatous ulcer on a patient's hand[18] in an event cited as the first true use of electricity in surgery. In 1926, American plant physiologist William Bovie created a diathermy machine that was employed on October 1st of that year by Dr. Harvey Cushing, a Boston neurosurgeon, to remove a highly vascular myeloma—an event that spawned the era of electrosurgery.[20]

At the turn of the 20th century, Simon Pozzi utilized high-frequency, high voltage, and low amperage current to treat skin cancers with a technique he called *fulguration*. Doyen improved on this technique by introducing a grounding plate to the generator and placing it underneath the patient. This allowed deeper penetration of electrosurgical energy into the tissues and produced an effect he termed *electrocoagulation*[18]—which would prove to have important applications for endometrial ablation.

In 1937, Bardenheuer[21] published *Elextrokoagulation (ELK) der Uterusschleimhaut*—electrocoagulation of the endometrium—and described a technique that was carried out in an office setting under light narcosis whereby he *blindly* introduced a unipolar electrode (a *Kungelsondenelktrode*) consisting of a 5–8 mm steel ball mounted onto a 12–16 cm nonconductive shaft (Fig. 3a and b). Bardenheuer, having observed some of the earliest late-onset endometrial ablation failures, stressed the importance of avoiding the coagulation of the internal orifice (os) to reduce the likelihood of hematometra formation and cyclic pelvic pain.

In 1948, Baumann[22] reviewed and reported a series of 387 women who were treated by Bardenheuer and summarized the findings of three groups of women who were followed for up to 15 years. Group I consisted of 324 women with "menorrhagia, metorrhagia, postmenopausal bleeding, adenomyosis, uterine polyps, and glandular cystic hyperplasia." Group II consisted of 58 subjects with myomas, while Group III subjects included five women with "postmenopausal menorrhagia." Baumann, who is generally credited with promoting Bardenheuer's technique, described a very low overall complication rate but recorded the limitations of this technique in the presence of large myomata.

Radium

In the years following the discovery of radium in 1898, there was what can be described as a cultural obsession with radiation and radioactivity and its potential use in society. A 1903 editorial in *The Manchester Guardian*[23] proclaimed that "radium must absorb some form of ambient energy quite unknown to us, to whose action the ordinary substances of the molecular world are indifferent. This energy must be all about us; we cannot gauge its possible resources; yet we knew nothing of it till yesterday… If only there were more radium in the world we could keep the earth warm when the sun went out." Within a few years of its discovery, radium's potential medical application was enthusiastically explored.

Shortly after the Curies' momentous discovery, its effect on human tissue was soon recognized. Two German scientists—Friedrich Walkoff and Friedrich Giesel—reported inflammation of the skin after radium exposure.[24] In 1901, Henri Becquerel accidentally burned himself after carrying a tube of radium in his waistcoat pocket. Pierre Curie—after conducting a self-experiment and producing a radium burn on his own arm—reasoned that radium might be useful in destroying diseased skin. Curie loaned some radium to a Parisian dermatologist, Dr. Henri Danlos, who established its beneficial effect on discoid lupus and other cutaneous lesions.[25] In addition to applications of superficial skin lesions, it became obvious that there were endless other ways in which radium could be applied—especially in the form of capsules or needles that could be inserted into body cavities and tumors. By 1903, Frances H. Williams, a Boston x-ray pioneer, obtained 100 mg of radium and Dr. Robert Abbe of New York experimented with intrauterine applications using radium from the Curies' laboratory.[26] One of Abbe's disciples, Dr. Williams Aikins, became an

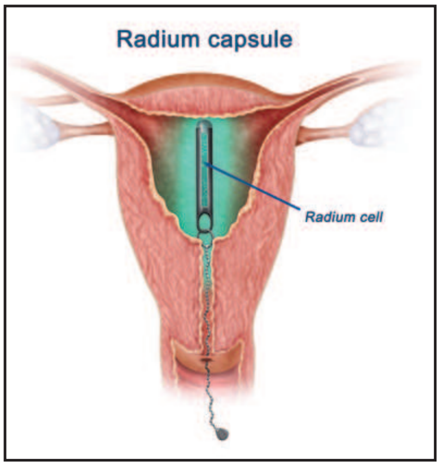


Figure 4. Intrauterine radium capsule application.

important proponent of "radiotherapy." In 1909, Aikins purchased a small supply of radium from the *Laboratoire Biologique* and subsequently opened the Radium Institute of Toronto—the first clinic in Canada to specialize in radiotherapy. Between 1910 and 1923, Aikins treated over 3,200 patients referred from as far as Saskatchewan and reported on 133 of them. In his treatise, *The Value of Radium in Curing Disease, in Prolonging Life, and in Alleviating Distressing Symptoms*[27] Aikins described the treatment of three women with uterine cancer as well as three others with menorrhagia, metrorrhagia, and uterine fibroids. Aikin's noted that "the ability to insert radium tubes into the uterus opened up a large and suitable field for utilizing the therapeutic qualities of radium." In 1922, he reported on the use of intrauterine radium (Fig. 4) to treat a wide range of pelvic conditions and specifically spoke of "its value in cases of uncontrollable uterine bleeding which were of non-malignant origin."[28] Unfortunately, since Aikin's subjects were all managed with varying doses and exposure, his work was of limited scientific value.

In 1917, Herbert Schmitz noted that "radium may be applied to benign and malignant diseases of the female pelvic organs. The benign disorders are myomata uteri, the hemorrhagic metropathies and chronic endometritides and cervicitides…." Schmitz noted that "Radium acts as Nature's curette and [is] hemostatic when applied to the endometrium."[29] He was also one of the earliest physicians to document and quantify the resiliency in endometrium in young women compared to their older counterparts noting that "the application of radium in the young to destroy endometrium requires large massive doses from 2,000 to 3,000 mgrm hours of gamma rays. The same result may be obtained in a woman approaching the menopause, or who is thirty-five years or over in age with only a third or fourth amount of milligram hours."[30]

In 1926, Forsdike[31] noted that "there is no doubt about the efficacy of radium in producing an artificial menopause… The object we have in view in menopausal hemorrhage is to convert the endometrium into connective tissue without the production of necrosis. We find this occurs experimentally and clinically when the hard gamma ray is used alone." Forsdike reported a series of 200 subjects, but noted that in the doses he utilized—53 mg of elemental radium placed in the uterus for 24 hours—that severe irritation of the bladder and rectum often resulted.

In 1937, Schulze[32] published the results of radium therapy in 204 women with "functional menorrhagia" who were observed for two to 20 years following treatment. Interestingly, six of the subjects were between the ages of 14 and 20, though the majority—136 subjects—were between the ages of 20 and 45. The doses of radium utilized varied from 400–1594 mCi/h, and 19 of the 204 women underwent a "repeat" treatment to achieve acceptable results. Schulze emphasized the unpredictable outcomes of this approach and also described some of the untoward side effects of radium therapy—specifically vaginal, vulvar atrophy, and dyspareunia. Schulze noted that a significant number of subjects reported "very bitter complaints over the marital difficulties which arose." He also observed that a "satisfactory dosage is difficult to establish since although, in general, the results are fairly uniform, the individual variation in response to a given dose is so great that the result is entirely unpredictable."

Perhaps the largest series involving radium in the treatment of women with intractable uterine bleeding was published by Barr et al.[33] Barr et al. noted that this form of treatment "greatly reduces the use of hospital beds, as well as the period of incapacity suffered by the patient." The authors routinely inserted tubes containing 50 mg of elemental radium utilizing an applicator immediately following a dilatation and curettage. The intrauterine radium capsules were kept in place for 30 hours and the patient was kept in bed for two days after the conclusion of irradiation. The patients were typically discharged on the sixth day of treatment. The authors quickly concluded that "it soon became a well-established rule that one does not undertake this treatment in women under the age of 40, and now as a result of the present investigation we believe that 42 is the lowest age at which the artificial menopause should be induced." Four hundred and thirteen (48.6%) subjects had no further bleeding while 278 (32.7%) reported only one menstrual period after treatment. Overall, 91.1% women reported satisfactory results. There were 15 complications including cystitis, proctitis, acute vaginitis, and thrombophlebitis. Interestingly, four patients developed a delayed neoplasm including a carcinoma of the uterus three years following treatment, one case of carcinoma of the cervix 10 years following treatment, one case of carcinoma of the rectum four years following treatment and one case of a "rodent ulcer" of the right lower eyelid six years following treatment.

Eventually, the use of radium for endometrial ablation fell into disrepute amid concerns regarding vulvo-vaginal atrophy and the management of recurrent vaginal bleeding, as well as its possible relationship to a variety of gynecologic cancers including endometrial, cervical, and sarcomatous lesions of the uterus.[34]

Radiation therapy

The use of x-ray therapy to control uterine hemorrhage was introduced in the early 20th century.[35,36] In 1923, Stewart et al.[37] summarized his findings on the treatment of 100 women with intractable uterine bleeding utilizing x-ray therapy. Stewart et al. identified two distinct groups—idiopathic hemorrhage occurring during the reproductive years and those associated with myomata. In his treatise, Stewart noted that x-ray affects both ovarian function as well as endometrium and, therefore, he recommends using it cautiously in subjects with "idiopathic hemorrhage occurring just at puberty or slightly after its onset." In a group of women whose ages varied from 35 to 55, Stewart noted that "the results obtained to date in these cases of idiopathic menorrhagia are excellent; they have shown no return of the bleeding." The authors concluded that when "balancing surgery

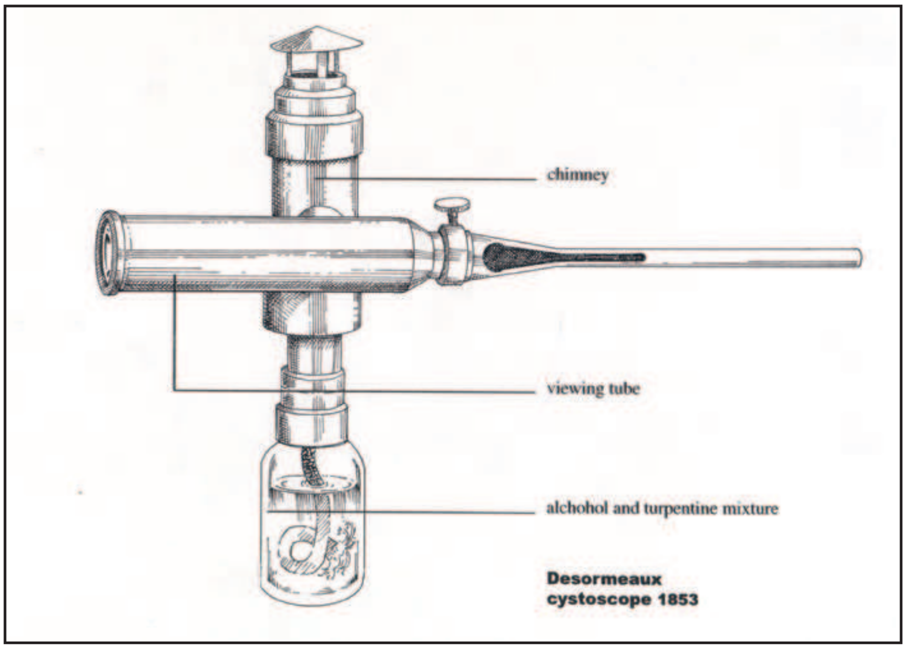


Figure 5. Desormeaux's cystoscope was also used for first operative hysteroscopy.

and radiation therapy in the treatment of these idiopathic hemorrhages, there seems no doubt that the latter is the method of choice. Its application is simple; the patient is not exposed to the risk of operation with its possible sequelae. No surgeon can afford to treat the method with indifference."[37] Eventually, the enthusiasm for radiation and x-ray therapy dissipated as awareness of its many adverse effects—vulvitis, proctitis, cystitis, and premature ovarian failure—were more widely appreciated.

Cryoendometrial ablation

The next foray into endometrial ablation came in 1967 when Cahan and Brockunier[38] reported the results of cryoendometrial ablation on six subjects utilizing a 6 mm diameter liquid-nitrogen-cooled probe in temperatures varying from -80 to -120°C. While satisfactory results were reported in five of the subjects no further studies were done until 1971 when Droegemueller et al.[39] described a similar technique utilizing Freon™-cooled probes (DuPont, Inc., Deepwater, New Jersey). Droegemueller reported that one of the deficiencies of this technique was that endometrium persisted at the cornua.

SECOND GENERATION ENDOMETRIAL ABLATION: EA UNDER DIRECT HYSTEROSCOPIC CONTROL

Second generation endometrial ablation (SGEA) represented a paradigm shift in the method used to accomplish selective endometrial destruction. While first generation techniques involved the blind application of chemical and various forms of thermal energy to obliterate the endometrium, the distinguishing feature of second generation techniques was direct visualization to destroy or remove tissue. This approach was ushered in by the introduction of the modern endoscope to facilitate both the diagnosis and treatment of intrauterine pathology—the hysteroscope. The nascent endoscope dates to 1804 when the Italian-German physician, Phillip Bozzini, created the *lichleiter*—a light transmitting device[40] that allowed him to inspect various body orifices, such as ear, urethra, rectum, bladder as well as oral and nasal cavities. This device would be modified by Antonin Desormeaux[41] who coined the term *l'endoscopie* and introduced his device at the Academie des Sciences in Paris in 1853 (Fig. 5). In 1869, an English physician, Commander Pantaleoni,[42] first used the Desormeaux cystoscope to chemically cauterize an endometrial polyp in a 60-year-old woman with postmenopausal bleeding. Many modifications and refinements—in optics, light sources, video cameras and distention media—would be required before the endoscope emerged as the precise diagnostic and operative tool we know today.

In 1959, Harold Horace Hopkins patented the quartz rod-lens system (Fig. 6) which eliminated the large number of air-glass interfaces found in classical endoscopes—the result was an image with unprecedented "brightness and clarity."[43] Hopkins' refinements allowed for the production of small-diameter endoscopes of the length required for a variety of surgical applications—an essential requirement for hysteroscopy. In 1960, Karl Storz utilized a flexible fiberoptic cable to transmit light away from a high intensity lamp to obviate the risk of inadvertent burns—the so-called "cold light source."[44] Over a half-century later, the refinements of Hopkins and Storz are at the very core of nearly every endoscope utilized today.

Another important development in the field of endoscopy occurred in 1962 when George Berci[45] successfully coupled a miniaturized black and white television camera to an endoscope and stored images on a 16 mm movie film. In the ensuing decades, miniaturized high-resolution color cameras were

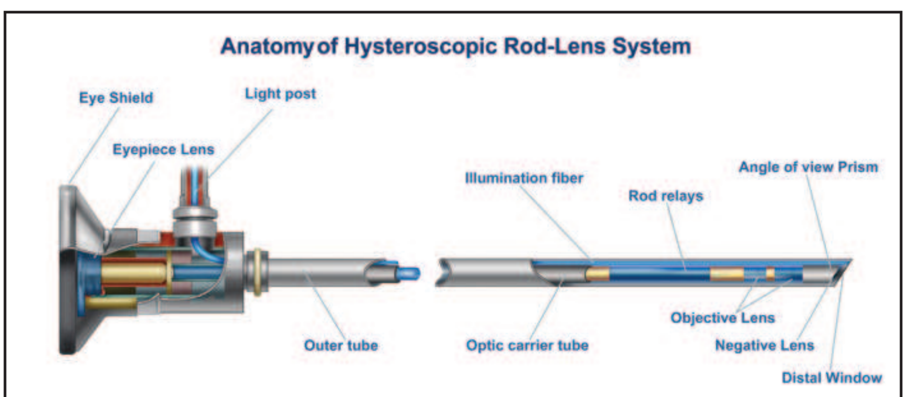


Figure 6. Hopkins quartz rod-lens system.

found in nearly all operating rooms and video-endoscopy (VE) emerged as an indispensable tool in modern surgery.[46] VE was critical to the development of hysteroscopy by eliminating the need for awkward and fatiguing physical postures while enabling documentation as well as teaching and participation of other operating room personnel.

With the improvements in video-augmented optics, the importance of hysteroscopy as a diagnostic and teaching aide was soon recognized, though its future as a reliable operative tool would require further innovations. Following a report by Levine et al.,[47] who employed 30% Dextran as an optically favorable distention media, Neuwirth et al.,[48] attempted the first transcervical hysteroscopic sterilization procedures. Neuwirth's procedures involved the use of a 6 mm diagnostic hysteroscope through which he passed a modified ureteral electrode containing a "special serrated electrocautery tip." Using a Bovie "diathermy unit" he attempted to thermally coagulate the uterotubal junction in a total of 17 subjects until "superficial charring occurred." Although the technique produced unreliable tubal occlusion, it served as an important historical step toward advancing both hysteroscopic surgery and endometrial ablation.

Hysteroscopic laser ablation of the endometrium

The modern era of SGEA can be traced to Goldrath et al.,[49] who, in 1981, co-located a Nd:YAG with a conventional red-lens hysteroscope and was able to "photovaporize" the endometrium under direct visualization (Fig. 7). The Nd:YAG laser was well-suited for this purpose as it could be effectively transmitted through a flexible quartz fiber and provided color-sensitive tissue penetration up to 4 mm beneath the endometrial surface. Goldrath's technique, was soon implemented by several pioneering physicians,[50-52] but was never widely adopted. There were at least four impediments to the growth of endometrial laser ablation (ELA). First, most gynecologists were not trained in diagnostic hysteroscopy. Second, the cost of a Nd:YAG laser in the late 1980s was prohibitively expensive for most institutions. In 1988, when the author performed his first ELA procedures, a 100 Watt Nd:YAG laser cost in excess of $100,000 USD or $1,000/Watt.

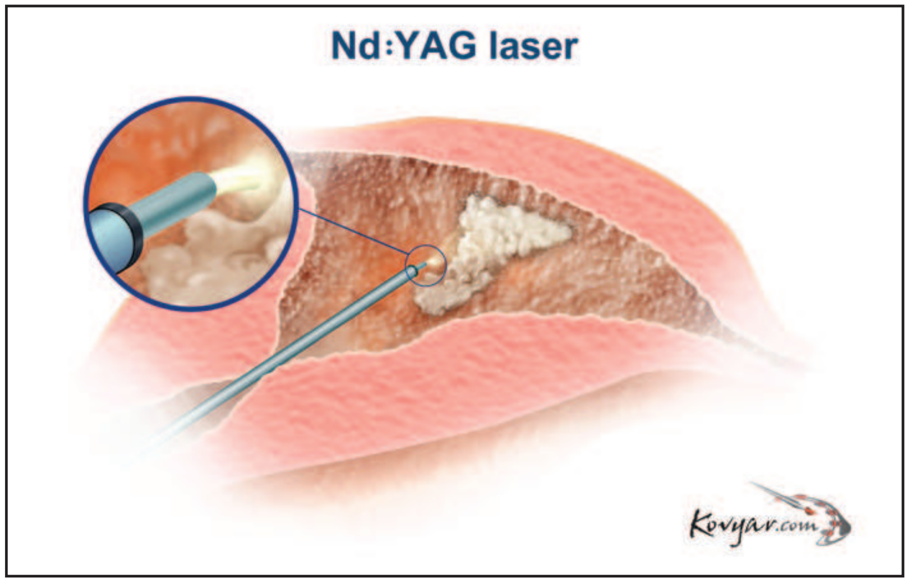


Figure 7. Endometrial laser ablation.

Third, the continuous flow hysteroscope was not yet available and reliable visualization of the endometrial cavity often escaped even the most motivated hysteroscopists. Fourth, fluid management systems—to accurately measure infusion pressure and net fluid absorption—had not yet been invented. The result, all too often, was inadequate uterine distention, poor visualization and, in some cases, fluid overload.

The gynecologic resectoscope, electrosurgery and endometrial destruction

In 1983—several years after Neuwirth's hysteroscopic sterilization attempts[48]—DeCherney et al.[53] utilized an inexpensive monopolar electrosurgical unit (ESU) as well as a conventional urologic resectoscope fitted with a wire loop to perform endometrial ablation. At the time, such generators were already available in most operating rooms—for 5% of the cost of a medical laser. Although DeCherney did not report many specific technical details, he demonstrated that an inexpensive energy source could overcome the economic impediments to EA. However, another issue remained—the ability to clear the operative field of coagulative debris which was a normal byproduct of EA. This important technical hurdle was addressed in 1989 when the U.S. Food and Drug Administration

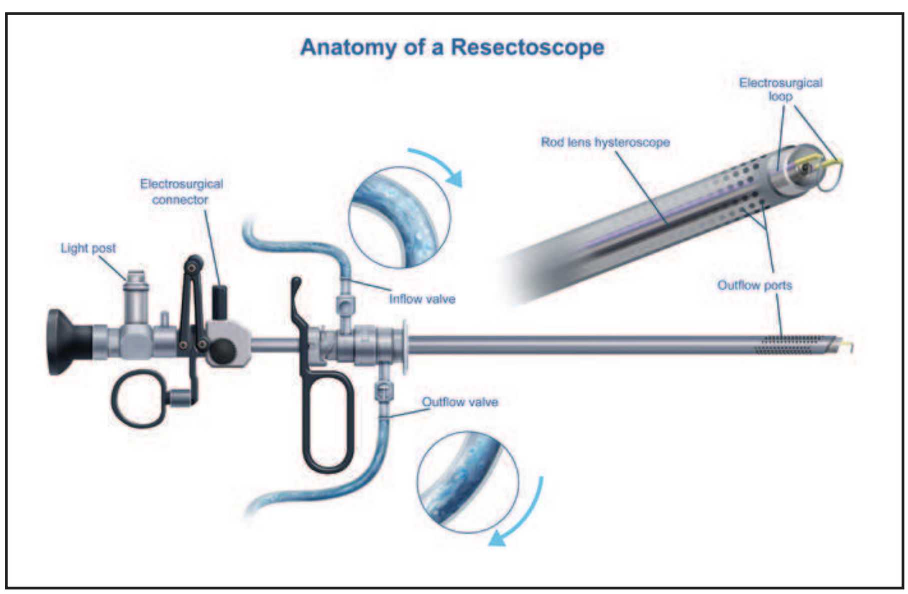


Figure 8. Continuous flow gynecologic resectoscope.

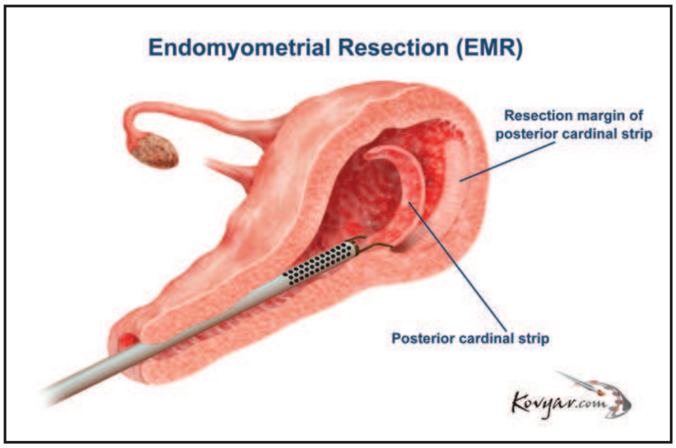


Figure 9. Endomyometrial resection (sagittal view).

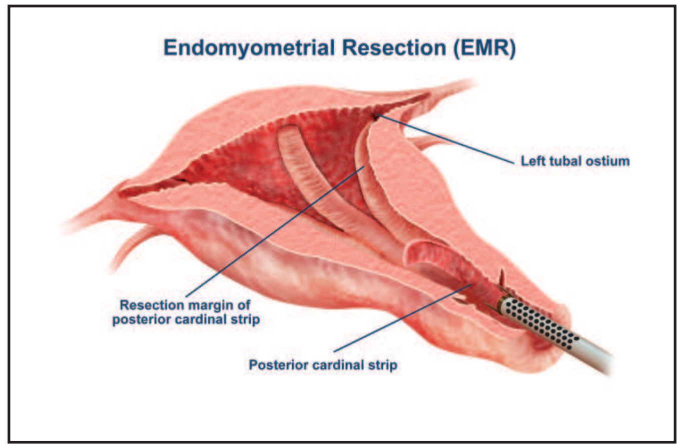


Figure 10. Endomyometrial resection (frontal view).

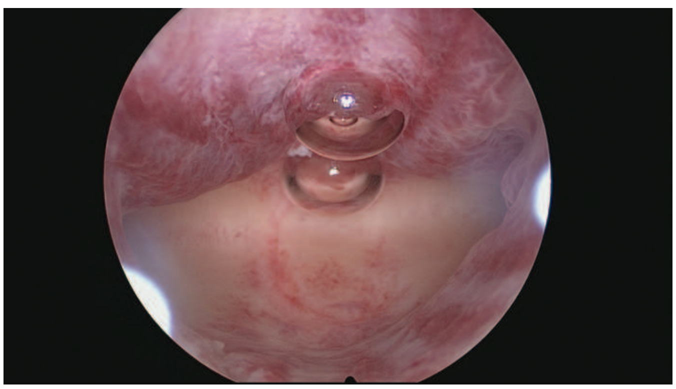


Figure 11. Uterine cavity prior to EMR.

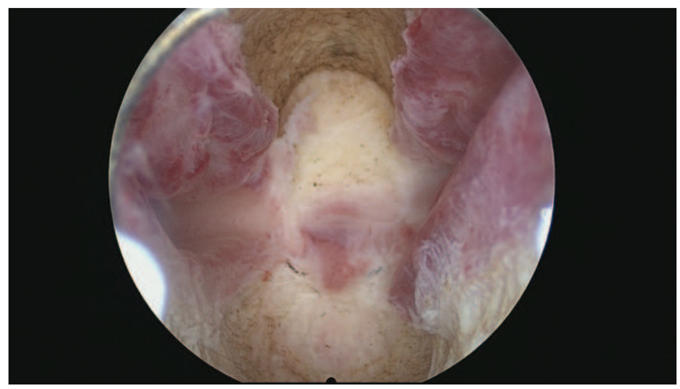


Figure 12. Uterine cavity following the removal of the anterior and posterior cardinal strips.

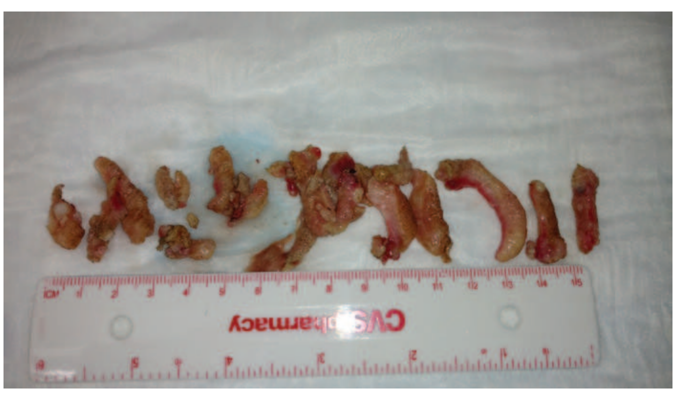


Figure 11. Uterine cavity prior to EMR.

Figure 12. Uterine cavity following the removal of the anterior and posterior cardinal strips.

approved the first continuous flow gynecologic resectoscope (CFGR) (Fig. 8). The CFGR, like its urologic counterpart, was equipped with a variety of coagulation—"rollerball" and "rollerbar"—electrodes as well as various "cutting-loops" that were better suited to removing specimens such as leiomyomas and endometrial polyps. In time, two schools of practice emerged on how best to employ the gynecologic resectoscope and its various electrodes.

The first group included pioneers such as Vancaillie[54] and Townsend et al.[55] who each published a series of subjects undergoing "rollerball" endometrial ablation while a second group was led by Magos et al.[56] who utilized the cutting loop electrode to remove the endometrium in a technique he called "transcervical resection of the endometrium" (TCRE). TCRE provided at least two advantages compared to resectoscopic EA—the production of a histologic specimen for analysis and the ease with which the technique could be adapted for the simultaneous removal of submucous myomas which Magos identified in nearly a quarter of his patients. In addition, TCRE could be performed without expensive medical pre-treatment of the endometrium.

Unfortunately, neither DeCherney et al. nor Magos et al. provided specific details on how to best accomplish the safe removal of endometrium to a spec-

Table I
Advantages of the continuous flow resectoscope compared to the Nd: YAG Laser

1. Compatible with an inexpensive energy source—electrosurgery.
2. Evacuates debris during the course of endometrial ablation.
3. Can be used for both ablation and resection techniques.
4. Obviates the need for expensive medical preparation of the endometrium.
5. Excellent specimen available for histologic analysis
   a. Of endometrium
   b. Of myometrium
6. Suitable for the concomitant management of submucous leiomyomas and endometrial polyps.
7. Easily adaptable to a wide variety of uterine sizes, configurations, and uterine anomalies.

ified depth throughout the uterine cavity. In 1994, the author[57] described a resection technique known as endomyometrial resection (EMR), a geometric approach to endometrial resection (Figs. 9-12) that produced a specimen with a known and predictable thickness of myometrium beneath the endometrial basalis. The differences between TCRE and EMR were not just geometric and quantitative. Hysteroscopic EMR produced far greater rates of amenorrhea compared to TCRE—84% vs. 27%—during the same initial six-month follow-up period. The resultant tissue specimen (Fig. 13a and b) following EMR included myometrium at least 3 mm beneath the endometrial basalis, thereby allowing one to make the histologic diagnosis of adenomyosis. In addition, complete endomyometrial resection often reveals endometrial pathology that escaped previous endometrial biopsies.

In summary, the continuous flow gynecologic resectoscope offered many advantages with respect to endometrial destructive techniques that are summarized in Table I. While these new advances stimulated interest within the gynecologic community, the disadvantages of these electrosurgical techniques also became apparent. The lack of hysteroscopy training, fluid management systems, and published guidelines for the use of distention media soon resulted in well-publicized reports of fatal complications. In 1993, Arieff et al.[58] and Baggish et al.[59] each reported a series of fatalities attributable to fluid overload, hyponatremia, and encephalopathy. In addition, the lack of proper training and credentialing for resectoscopic surgery soon resulted in uterine perforation and numerous cases of visceral injury. Within a short period of time, the search for safer methods of endometrial ablation began and the medical device industry soon responded. The result was extensive innovation to produce safe endometrial ablation. Ironically, these techniques became known as "Second Generation" by numerous authors.[60-64] The moniker itself implied both an evolutionary and an improved process, but they were simply a return to an era that began in the late 19th century—the blind application of energy to destroy the endometrial cavity. STI

AUTHOR'S DISCLOSURES

Dr. Wortman has no conflicts of interest to disclose.

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