Chapter 2

Pelvic Imaging using Sonography and Hysterosonography in the Female Patient

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Introduction

This chapter will focus on the use of ultrasonography and sonohysterography (SIS) as screening tools for the assessment of normal and abnormal female pelvic anatomy. An overview of the principles of ultrasound, the technique of both and normal and abnormal findings will be discussed. Further, a focus on SIS and its newer diagnostic applications will be reviewed and compared to traditional modalities including hysterosalpingogram (HSG) and ultrasonography.

Historical Perspective

It is difficult to imagine the field of obstetrics and gynecology without the aid of ultrasonography, but this technology has only been applied in medicine for the last 60 years. The earliest recorded use of ultrasonography in obstetrics and gynecology was in 1958 by Dr. Ian Donald and his team from Glasgow after years of research on the subject [1,2]. Since the early 1950s, Donald had suspected that sonar detection, which at the time was only used in marine vessels for measuring distance to the ocean floor, could be applied to medical diagnostics. His work contained ultrasonographic images of gynecological masses and the fetus, obtained through the use of a compound contact scanner, the first scanning machine with medical practicality [2,3]. During the next decade, clinicians and physicists worked to improve and refine the technology.
As equipment and machines became more advanced with higher quality resolution images, clinical studies using ultrasound technology began. Studies from the 1960s and 1970s focused on assessing the placenta, fetal biometry, and fetal abnormalities, which further expanded the scope of ultrasonography. Transabdominal sonography (TAS) was developed first but is limited due to low frequency of the probe, need to penetrate the abdominal wall and lack of proximity to the pelvic structures being studied. Transvaginal ultrasonography (TVS), first reported in the 1980s, offered the ability to obtain high resolution images, and today is the preferred route for most gynecologic ultrasounds when assessment is needed within the pelvic cavity [4].

Austrian physicist, Christian Doppler, was the first to illustrate the Doppler effect in 1842, which paved the way for Doppler imaging. Originally called color flow mapping, Doppler imaging allows for visualization of fetal vasculature in addition to fetal movement [5,6]. This technique combined the ultrasonic mapping of anatomy with fluid velocity information superimposed in color over grey-scale images of the anatomy [7]. However, it wasn’t until the early 1990s that color Doppler technology enhanced the diagnostic value of real-time ultrasonographic digital scanning machines [3].

More recent advancements in ultrasound technology have included three-dimensional (3D) sonography. One of the first efforts utilizing 3D sonography was with fetal visualization developed by Dr. Szilard in 1974. Dr. Szilard’s machine used stroboscopic illumination, which resulted in image transparencies being projected onto a set of screens set along a helix inside a rotating drum [8]. With this method, color and brightness of images varied with depth and thus a 3D image could be discriminated. Baba and his colleagues developed a more modern 3D ultrasound technique in 1989 that was used to visualize live fetuses in utero [9,10]. An additional benefit of 3D ultrasonography is that this technology has obviated the need for MRI imaging to confirm the diagnosis for fetal and gynecologic abnormalities, including müllerian abnormalities [11].

Another significant advancement was the application of saline infusion sonohysterography (SIS), which is a refinement of ultrasonography that provides an enhanced view of the uterine cavity while retaining the convenience and safety of simple ultrasonography. Nannini et al. first reported use of this procedure in the 1980s, and today has achieved widespread use [12]. The study involves the transcervical passage of a catheter and the distention of the uterine cavity with saline infusion, thus improving the clinician’s ability to detect endometrial pathology [13].

Finally, the application of hysterosalpingo-contrast sonography or HyCoSy, has been used to assess tubal patency, as the normal fallopian tube is not visible using only ultrasound technology [14]. Since the beginning of HyCoSy use in the 1980s, clinicians have experimented with
several contrast agents to enhance transvaginal ultrasound visualization of the fallopian tubes. Others have employed saline-air mixture either by agitating a syringe of saline and air to create injectable air bubbles or by intermittent infusion of air followed by saline and more recently, the introduction of a saline-air device that delivers alternating doses of air and saline in a constant and controlled fashion has been applied [15,16].

The benefit of modern ultrasound in medicine extends to all general obstetrics and gynecology. Not only is ultrasonography an excellent tool for tracking fetal development during pregnancy, but the technique has proven to be a valuable tool for visualizing female pelvic anatomy and evaluating any cervical, uterine, tubal, or ovarian abnormalities. Ultrasonography and SIS are two of the most important technologic advancements introduced into the practice of obstetrics and gynecology.

Ultrasonography

The use of ultrasonography has become widespread given that it is a safe, non-invasive, and readily available tool in the office setting and has been advocated as a first-step assessment of uterus and fallopian tube anatomy for patients with abnormal uterine bleeding, pelvic pain and pregnancy. Ultrasound can also provide information regarding normal physiologic changes including synchrony between ovarian findings and normal endometrium. The indications to evaluate pelvic anatomy include pelvic pain, infertility and abnormal uterine bleeding in both peri- and post-menopausal women [17-19]. The gold standard has always been surgical evaluation, utilizing laparoscopy and/or hysteroscopy. While these procedures are both sensitive and specific, they generally require performance in an operating room setting under local and/or general anesthesia and pose significantly greater risks and costs.

TAS is considered complementary to TVS. TAS, which employs lower-frequency transducers with higher tissue penetration, is a practical way to visualize pelvic structures located more than 6 to 8 cm from the vaginal vault. With the development of 7.5 MHz transducers, TVS has become the technique of choice because it has afforded a high degree of real-time resolution and structural detail of the female pelvis enabling evaluation of uterine and pelvic pathology [20]. Findings on TVS that have been used to describe uterine pathology include endometrial thickness, heterogeneity, cavitory lesions and myometrial involvement to determine which patients should undergo further investigation.

Despite the increased use of high resolution abdominal and TVS, it has limited usefulness in identifying the exact location of endometrial cavity pathology [21]. Several factors may present challenges in diagnosing endometrial pathology with precision. These factors include small lesions that project into the cavity, distortions of the uterine anatomy and the phase of the menstrual cycle at the time of imaging [22]. Moreover, the usefulness of endometrial thickness measurement is predicated on visualization of
a clear longitudinal stripe of endometrium. This may be reduced in cases of endometrial distortion due to uterine fibroids or abnormal uterine angulation [23].

Evaluation of the pelvis under ultrasound should be performed systematically for a complete survey of pelvic anatomy. The uterus should be carefully evaluated in both the longitudinal axis, which normally measures 7.5cm from the external os to the upper fundus and the transverse axis, which measures 5cm from cornua to cornua for the presence of anomalies of the cervix and the uterus (Figure 1). In particular, the size and number of all intramural and submucosal leiomyomata, any suspected endometrial polyps or uterine malformations should be described.

Version and flexion of the uterus should be noted and are useful information when performing endometrial sampling for abnormal bleeding, endometrial dating or intrauterine inseminations. Notations of free peritoneal fluid most commonly seen in the posterior cul-de-sac should be documented. While this is a normal finding in most women at any time during the menstrual cycle, an increase in free pelvic fluid can be suggestive of such findings as ovulation, signs of ovarian hyperstimulation syndrome (OHSS) in those undergoing ovulation induction or ascites associated with ovarian malignancies [24].

Normal tubal anatomy is very difficult to assess by routine TVS. When the tubal lumen is identified, this strongly suggests pathology. A hypoechogenic tubular structure is highly suggestive of distal tubal obstruction or hydrosalpinx (Figure 2).
Often the evaluation of the adenexa by TVS cannot be accomplished with a one-hand technique. The ultrasonographer may use his or her non-dominant hand as an abdominal support to help mobilize and better define pelvic structures and assess for pelvic tenderness, which is considered an extension of the pelvic exam [25]. Most ultrasound machines provide a pedal remote for freeze frame and image capture and storage.

TVS of the ovary should report the dimensions in three perpendicular planes. For those undergoing controlled ovarian hyperstimulation (COH), the pre-antral follicle count has been identified as a predictor of ovarian response [26]. The normal ovary can show pre-antral follicle count between 2-10 mm in diameter. A multi-follicular pattern of the ovarian cortex (string of pearls) has been noted in many patients with polycystic ovarian syndrome (PCOS), but can be seen in up to 10% of normally ovulating women [27]. The recognition of larger functional cysts may represent persistent unruptured follicles or corpora lutea.

There are several physical principles that need to be applied in order to optimize the image quality at the time of ultrasound. The actual image is produced by sending sound waves at high frequencies. Sound information returns from reflections off organs and other tissues depending on the solidity of the structures. These echoes in turn produce a picture representation of the imaged structures. The detail of the images improves with high frequency sound waves with short pulse lengths and narrowly focused beams. The higher the frequency, the better the resolution, but depth of penetration decreases with increased frequency. The probe should be used which offers the highest frequency that can penetrate the depth to be studied [28]. Most probes are electronic curvilinear probes which offer versatility by automatically changing frequencies depending upon the structure studied [29].

In addition to resolution, selections for the pelvic organs to be studied and optimizing the actual image can be undertaken to improve the picture. The depth of the scan should be chosen so that as little depth as possible is used to have the best resolution. The power level refers to the amount of energy produced by the transducer while the gain refers to the amount of amplification of the returning sound waves. Increased power can improve the quality of the image but may produce more artifacts. The gain should be adjusted for overall brightness of the image. The focal zone should be set in the area of the organ being studied. The dynamic range should be set on low for cystic structures and on high for solid structures.

Most ultrasound machines are very versatile, allowing several probe and imaging options to maximize picture quality. Current modalities for ultrasound include B-mode (gray-scale image), M-mode (motion), Doppler (flow studies at a single point), color Doppler (flow studies covering an area of the image) and three-dimensional (3-D) imaging. Most real-time sonography is performed in B-mode [30]. An M-mode ultrasound is frequently used for assessing fetal heart rate activity [31]. When an ultrasound study is performed, applying a few physical prin-
Principles to the selection of the various parameters available on the machine and probe can enhance the picture quality and provide the desired diagnostic information to its fullest extent.

**Normal Ultrasound Findings**

**Normal Physiologic Changes**

The pelvis of a reproductive age woman is a dynamic area undergoing monthly cyclical changes, which should be evidenced by a synchrony between the ovary and the endometrium. With menses, there is a sloughing of the endometrium down to the basalis, which sonographically appears as a thin, linear echogenicity, while the ovary has numerous small sonolucencies suggestive of recruitment of pre-antral follicles [32,33] (Figure 3a and 3b).

![Figure 3a: Sonographic appearance of the endometrium, after sloughing down to the basalis. Note the thin, linear echogenicity indicated by the arrows.](image)

![Figure 3b: Numerous small sonolucencies suggest recruitment of pre-antral follicles.](image)

The recruitment of the dominant follicle and estrogen production induces proliferation of the endometrium, which has a multi-layered trilaminar appearance with a central echogenicity surrounded on each side by a sonolucent “halo” culminating in an echogenic interface to the compact inner myometrium [31] (Figure 4).

Concomitantly, a dominant follicle can be seen as early as day 8 to 9 of the cycle, which will exponentially grow by 2mm per day. On day 14 of an idealized cycle, the follicle, now 20-25mm at its largest diameter, will ovulate (Figure 5) [34,35]. Enhanced cervical mucus will correspondingly reveal a hypoechogenic line (Figure 6).
Figure 4: Proliferation of the endometrium with a multi-layered trilaminar appearance and central echogenicity surrounded on each side by a sonolucent “halo.”

Figure 5: Peri-ovulatory follicle.

Figure 6: Cervical secretions at ovulation.

Figure 7: Corpus Luteum that can be confused with endometrioma and teratoma.
The presence of a corpus luteum or free fluid in the cul-de-sac is highly suggestive that ovulation has occurred. The corpus luteum often appears as a thick walled, irregular structure sometimes containing internal echos, corresponding to blood and debris [36]. This finding can be difficult to differentiate from an endometrioma or neoplasm and often requires repeat scanning in the following follicular phase to clarify (Figure 7).

Figure 8: Hyperechogenic pattern of luteal phase endometrium.

Corpus luteal progesterone production induces characteristic changes of the endometrium as it converts from the follicular phase to secretory phase. Endometrial growth typically plateaus 5 days after the LH surge reaching an average diameter of 14 mm. The hypoechoic endometrium transitions to homogeneous and echogenic pattern by the mid-luteal phase [37] (Figure 8). Real-time ultrasound can also reveal myometrial contractions that appear as waves in the endometrium. These contractions appear to progress from the cervix to the fundus in the late follicular phase and have been shown to increase in frequency and intensity around ovulation [38].

Early Pregnancy

In early pregnancy, a blastocyst forms, comprised of an amniotic cavity, a bilaminar embryonic disk, and the primary yolk sac [39]. The blastocyst burrows into decidualized endometrium and the surrounding trophoblast proliferates, producing primary chorionic villi in the decidual reaction. This cavity of fluid surrounding the growing embryo is known as the gestational sac and appears sonographically as an echogenic ring at four weeks gestational age and grows at a rate of about 1 mm a day through the 9th week of pregnancy. However, it may not be seen until the end of the 5th week when serum hCG levels have risen to 2500 to 3500 mIU/mL (Figure 9) [40].

Events in early pregnancy follow a fairly consistent pattern. At approximately 5 weeks of gestational age, a gestational sac is first seen. At this early stage of pregnancy, the gestational sac already contains the yolk sac, embryonic disk and amnion, but these structures are too
small to visualize on ultrasound [41]. When these structures are not visualized in the gestational sac, gestational age can be estimated by determining the mean sac diameter and adding 30 to the sac size in millimeters to give gestational age in days [42]. The yolk sac can be visualized sonographically at approximately 3 to 3 ½ weeks post-conception when the gestational sac has reached a mean diameter of 8mm to 10mm. This structure of fetal origin is extraamniotic and appears as a thin, bright echogenic rim around a sonolucent center, measuring 4 cm in diameter (Figure 10) [43].

The yolk sac will persist for up to 10 weeks and is eventually incorporated into the amnion. Its presence by 5 weeks and 4 days confirms the diagnosis of an intrauterine pregnancy and excludes an ectopic pregnancy except in rare cases of heterotopic pregnancies. The embryonic pole appears adjacent to the yolk sac and cardiac activity (60 to 90 bpm) may be detected in a 2mm to 3mm embryo and is detected in a normal pregnancy when the embryo reaches 5mm. The fetal pole grows at a rate of about 1mm per day starting at the 6th week of gestational age. An accurate way to date the pregnancy is to add the length of the fetal pole (in mm) to 6 weeks [44]. Identification of fetal cardiac activity after 8 weeks from the last menstrual period is associated with a continuation to live birth rate of 95% or greater [45].
Variations from the expected norm are worrisome for early pregnancy failure, pregnancy of unknown location (PUL), and ectopic pregnancy. Ectopic pregnancies comprise 1-2% of gestations and may have serious morbidity and mortality issues as well as implications for the future reproductive health of the patient [46]. Ectopic pregnancies most commonly implant in the fallopian tubes, but may occur in the cervix or ovary [47,48]. Approximately 1 in 8000 to 30,000 pregnancies is reported to be heterotopic where they occur both inside and outside the uterus (Figures 11a, 11b and 11c) [49]. Clinicians should investigate for pregnancies of unknown location (PULs) when an initial ultrasound is inconclusive or an intrauterine or ectopic pregnancy is not definitively visible [50]. When measured hCG levels are above 2000 mIU/mL, the most likely diagnosis is a non-viable intrauterine pregnancy, which occurs approximately twice as often as an ectopic pregnancy and a follow-up ultrasonography should be done to confirm the diagnosis with endometrial sampling to assess for chorionic villi prior to treating with methotrexate [51]. Unfortunately, in those with a PUL, it has been reported that women with viable intrauterine pregnancies have been treated with methotrexate for presumed ectopic pregnancies leading to miscarriage or birth defects in a live-born baby [51].
Pelvic Anatomy

The non-distended fallopian tube is difficult to visualize on TVS due to its small diameter [52]. On transverse views of the uterus, the origin of the fallopian tubes may at times be appreciated by following the invagination of the endometrium from the cornual region, which represents the tubal ostia, laterally into the adnexal region. Intraperitoneal fluid may enhance visualization of the fallopian tubes [53]. TVS can also depict other pelvic structures including loops of bowel and pelvic blood vessels. The internal iliac arteries are typically between 5 and 7 mm in diameter and pulsate, whereas the iliac veins are larger (approximately 1 cm), but do not pulsate [45]. Pathologic signs of the fallopian tube visible with TVS include the “cogwheel” sign, indicative of acute salpingitis and the “beads-on-a-string” sign, which suggests chronic salpingitis (Figure 12a and 12b) [54,55].

Postmenopausal Changes

In contrast to the normal reproductive age woman, cyclical changes will not be present in post-menopausal women. The hypo-estrogenic endometrium would be expected to have a fine, thin linear echogenicity with an intact hypoechoic zone surrounding it [56] (Figure 13). The postmenopausal ovary has been described to become more linear than ovoid and loses the appearance of cortical sonoluent areas consistent with pre-antral follicles [57]. Visualization of the pelvic anatomy can be difficult.
particularly in some post-menopausal women who have significant atrophy and narrowing of the introitus, precluding the use of the transvaginal probe. A significant number of post-menopausal women will exhibit adnexal findings, including up to 3% with unilocular cysts. Bailey et al. reported that unilocular ovarian cysts <10 mm in diameter in asymptomatic postmenopausal women or women >50 years of age are associated with minimal risk for ovarian cancer, with close to 50% spontaneously resolving within 60 days [58].

**Figure 13:** Atrophy of the hypoestrogenic endometrium.

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**Sonohysterography**

In 1981, Nannini et al. were the first to describe what they termed “echohysteroscopy” [59] (Figure 14). The terms sonohysterography (SHG) or saline infusion sonography (SIS) were later provided by Parsons to describe the instillation of saline into the uterine cavity during ultrasound. Compared to traditional diagnostic modalities including sonography and hysterosalpingogram, SHG/SIS provides a high level of diagnostic accuracy [60]. Moreover, SHG/SIS has some major advantages over HSG, including simplicity, cost, minimal invasiveness, and absence of ionizing radiation.

**Figure 14:** Echohysteroscopy or sonohysterography.
Sonohysterography is simple to perform and by virtue of distension allows detailed visualization of the endometrial lining and possible intracavitary defects, including polyps, submucosal leiomyomas and endometrial carcinoma [61]. A systematic approach to performing this procedure is essential. One must inform the patient about potential complications including bleeding, infection and perforation. While the risk of infection is rare and has been reported to be <1%, it is important to consider prophylactic antibiotics for patients having a history of pelvic inflammatory disease and those who require systemic bacterial endocarditis prophylaxis [62]. Routine use of nonsteroidal anti-inflammatory agents 30 minutes prior to the procedure has been recommended to reduce discomfort. Sonohysterography should be performed in the first half of the menstrual cycle (days 4-12) following the cessation of bleeding so that pregnancy is ruled out and intracavitary lesions are more easily seen on the background of a thin proliferative phase endometrium [63].

Typically, a comprehensive baseline ultrasound of the entire pelvis is performed. After this, the probe should be removed, a speculum inserted and the vagina and cervix cleansed with an antiseptic solution and a catheter introduced into the uterine cavity just passing the internal os (Figure 15). When advancing the catheter, one should avoid touching the fundus of the uterus with the tip of the catheter as this can cause pain and/or produce a vasovagal response. Intracervical placement of a balloon catheter is a comfortable method for patients and allows superior visualization of the entire endometrial cavity throughout the procedure [64]. The catheter should be primed with saline to minimize the infusion of air bubbles that can cause image artifact and pain.

Figure 15: Shadowing of catheter.

Following careful removal of the speculum to avoid dislodging of the catheter, the transvaginal or abdominal probe is placed in the proper position. Although either can be used, most physicians/technicians prefer the high resolution of the transvaginal approach. There are several important considerations when performing sonohysterography:
Timing

The procedure should be performed within the first 10 days of spontaneous or progestin-induced menstrual flow, as menstrual blood or clots may be misinterpreted as pathology (polyps/adhesions) (Figures 16a and 16b).

Additionally, the introduction of fluid in the cavity during menses can create artifacts. Thus, it is recommend-ed to avoid the procedure when a patient is having heavy bleeding [65]. If the study is performed during bleeding and small lesions (<10 mm) are seen, repeating the exami-nation during a bleeding-free interval may be advisable.

Instrument Placement

A balloon system is recommended for the patulous cervix. For cases of cervical stenosis, various options to gain entry into the cervical canal have been utilized. These include guide wires that are placed through the catheters to stiffen the catheter or using a tenaculum to place traction on the cervix.

Fluid Instillation

Several solutions have been used to obtain optimal imaging, including saline, Ringer’s lactate, and glycine 1.5%. These solutions should be warmed and connected to the catheter system. The initial infusion rate should not exceed 5 mL/minute and can be adjusted based on the patient’s response and comfort level [63]. In a rand-onized clinical trial assessing if intrauterine lidocaine
minimized pain during hysterosalpingography, patients received NSAID and 2 mL buffered 2% lidocaine or 0.9 % sodium chloride (placebo) instilled into the uterus. There appeared to be no difference in peak pain scores between intrauterine lidocaine and placebo groups [66].

**Procedure**

The uterus should be scanned in the longitudinal plane fanning from one cornua to the other and in the transverse plane from the top of the fundus to the cervix. Most cases should not require more than 10 to 20 cc of fluid. Inadequate uterine distension may result in poor visualization whereas overzealous distension may obscure pathology or extent of disease. All images should be recorded as still images or on videotape for permanent records. After completion of the evaluation, the balloon should be deflated and fluid aspirated prior to removal of the catheter to minimize uterine cramping following the procedure. The entire procedure should last on average 3 to 10 minutes. The patient should rest for 5 to 10 minutes to avoid post-procedure syncope.

Common problems encountered during sonohysterography include the following:

- Air trapped in cavity: To prevent this, flush the catheter system prior to sonohysterography.
- Mechanical shearing of endometrium: This is due to overzealous placement of the catheter, which can shear the endometrium and cause false positive results (Figure 17).
- Mechanical interference with visualization: To avoid this, deflate the balloon at the conclusion of the procedure to adequately assess the lower uterine segment and cervical canal for any pathology. If possible, use fluid instead of air to inflate the balloon.

Sonohysterography is used for a number of clinical indications. These include: (1) Abnormal uterine bleeding; (2) Monitoring tamoxifen therapy; (3) Infertility; (4) Clarification of ultrasound findings of thickened endo-
metrium with minimal tissue obtained on endometrial sampling; (5) Suboptimal ultrasound visualization of the endometrial stripe secondary to severe angulation of the uterus or pathology [67].

**Endometrial Abnormalities**

Findings on TVS have been used to detect endometrial pathology including endometrial thickness, heterogeneity, cavitary lesions and myometrial involvement to determine which patients should undergo further investigation. Abnormal uterine bleeding in postmenopausal women is a harbinger of endometrial cancer. This disorder occurs in 1-2 per 1000 postmenopausal women per year and is one of the most common cancers in the female, exceeded in frequency only by carcinoma of the breast, colon and lung [68]. Thus, all women with abnormal uterine bleeding should undergo screening prior to hormonal manipulation for abnormal bleeding.

Historically, the standard diagnostic procedure has been dilation and curettage (D&C) with or without hysteroscopy. This recently has fallen out of favor and is often replaced by outpatient endometrial sampling via suction devices. However, several studies have revealed that suction sampling can miss a significant number of lesions. Goldschmit et al. performed suction sampling in 135 premenopausal women prior to D&C. Eighteen women had hyperplasia, in whom Pipelle sampling missed the diagnosis in 7 (39%) [69] (Figure 18).

![Figure 18: Endometrial Biopsy demonstrating localized endometrial sampling.](image)

In patients undergoing hysterectomy for endometrial carcinoma, Guido et al. demonstrated that among 65 patients, Pipelle sampling provided adequate tissue for pathologic evaluation in 63 (97%). Malignancy was detected in only 54 patients (83%). Of the false negatives (n=11), five (8%) had carcinoma confined to endometrial polyps and three (5%) had tumor localized to less than 5% of the surface area [70]. These studies demonstrate that 15% or less of the endometrial cavity is sampled using these suction devices, and although useful for detecting global disease, they are frequently inadequate for discovering disease confined to a localized area or polyp.
Figure 19: Thickened endometrium in postmenopausal woman.

The use of TVS is a sensitive non-invasive method for detecting endometrial thickness. It has been advocated as a useful predictor of endometrial pathology, including carcinoma, hyperplasia, polyps and submucosal uterine fibroids [71]. Many studies suggest that an endometrial thickness ≤5 mm can exclude endometrial pathology, thus obviating the need for other invasive procedures. While this threshold may apply to postmenopausal women in whom endometrial thickness remains constant, patients receiving postmenopausal hormone treatment or tamoxifen [72,73] and premenopausal cycling women are more difficult to categorize by this single cutoff [74]. Moreover, a reliable assessment requires that the endometrial echo must be completely seen in a longitudinal axis, surrounded by an intact hypoechoic junctional zone (Figure 19). Often, angulation of the uterus or coexisting pathology can distort the endometrium and thus decrease the predictive value of ultrasound imaging.

Figure 20: Endometrial hyperplasia.

Much credence has been placed on the diagnostic accuracy of endometrial thickness and the risk of endometrial hyperplasia and carcinoma [75] (Figure 20 and Figure 21). The Society of Radiologists in an Ultrasound-Sponsored Consensus Conference Statement [76] recommended that either TVS or endometrial biopsy could be used safely and effectively as the first diagnostic step in patients with abnormal uterine bleeding. They point out
that similar sensitivities are seen for each of these modalities. However, many studies regarding TVS and endometrial thickness suffer from methodologic shortcomings. Two systematic quantitative reviews of available published literature in those with postmenopausal bleeding were performed to better assess the diagnostic accuracy of endometrial thickness [77,78]. ACOG released a committee opinion based on these reviews, stating that TVS can be useful in the triage of these patients [79].

Gupta et al. used stringent criteria, including a clear prospective protocol, where 57 studies with 9031 patients were included in their analyses [77]. The commonest cut-offs for endometrial thickness were 4 mm and 5 mm. Using pooled-estimates, a positive test raised the probability of carcinoma from 14% (95% CI 13.3-14.7) to 31.3% (95% CI 26.1-36.3), while a negative test reduced the risk to 2.3% (95% CI 1.2-4.8) using ≤5mm and 1.2% (95% CI 0.4-2.9) using 4 mm. Tabor et al. analyzed nine studies representing 3,483 women without endometrial cancer and 330 women with endometrial cancer, which revealed that 4% of endometrial cancers were still missed with a 50% false positive rate [78]. Thus, it would appear that women with postmenopausal bleeding and an endometrial thickness >5 mm on TVS should have endometrial sampling to rule out neoplasia. However, in those with an endometrial thickness ≤5 mm, while there is fair certainty that neoplasia can be ruled out, it is not 100% accurate.

The use of TVS in asymptomatic women has also been evaluated to identify endometrial disease. The PEPI (Postmenopausal Estrogen/Progestin Interventions) trial evaluated 448 women who were randomly assigned to receive placebo or one of four active hormone treatments over three years [80]. Women were screened with TVS and the findings were correlated with findings from endometrial biopsies. Using a threshold value of 5 mm, TVS has a high negative predictive value (NPV) (99%), but a poor positive predictive value (PPV) (9%) for detecting endometrial abnormalities. They concluded that TVS is not a useful screening test in asymptomatic postmenopausal women regardless of their use of hormone treatment.
Fleisher et al. studied 1,926 asymptomatic postmenopausal women [81]. Using a 6 mm threshold, 1,833 were observed to have an endometrial thickness ≤6 mm and 1,750 underwent endometrial biopsy. Similarly, the NPV was excellent (>99%), but the PPV was poor (2%).

In addition, a more recent meta-analysis reporting on 11,100 asymptomatic postmenopausal women not using HRT, found that the use of endometrial thickness as a screening test for endometrial carcinoma and atypical endometrial hyperplasia is not justified [82]. Their systematic review determined sensitivity and specificity of TVS endometrial thickness measurement in the prediction of endometrial carcinoma were 0.83 (95% CI, 0.19–1.00) and 0.72 (95% CI, 0.23–0.95) for a 5-mm cut-off and 0.33 (95% CI, 0.04–0.85) and 0.94 (95% CI, 0.92–0.96) for a 6-mm cut-off [81]. As a result of these findings, screening for endometrial abnormalities in asymptomatic postmenopausal women has not been universally advocated.

In premenopausal women, endometrial thickness varies with the menstrual cycle with a range of 6 to 12-mm considered normal, while others have reported a mean maximal endometrial thickness of 10 to 12-mm during the menstrual cycle [31]. In reproductive age women with abnormal uterine bleeding, thickened endometrium can be attributable to neoplasia, polyps, leiomyomas and retained products of conception [83]. TVS is not a reliable predictor of pathology in this population. Dueholm et al. reported that polyps are the most frequently missed endometrial pathology [84] (Figure 22). Sensitivity using TVS has been reported to be 80% for endometrial polyps (n=344) and 94% for submucosal leiomyoma [83].

Sonohysterography enhances the diagnostic accuracy of TVS in women with abnormal uterine bleeding. This test allows for differentiation of isolated submucosal defects from more diffuse endometrial thickening [83,85]. Neck et al. compared TVS and sonohysterography in 199 women [85]. He found that 6.7% (n=8) had an abnormal TVS, while an abnormal sonohysterogram was seen in 34.5% (n=41). Tehranian et al. assessed 90 premenopausal women who presented with abnormal uterine bleeding
and determined that the diagnostic accuracy of sonohysterography was 89% for the normal endometrium, 90% for endometrial polyps, 99% for submucosal fibroids and 94% for endometrial hyperplasia [83].

Dubinsky et al. prospectively evaluated 148 postmenopausal women with abnormal bleeding who underwent aspiration endometrial biopsy [86]. Sonohysterography was performed in 81 of these women who had an endometrial thickness >5-mm and identified 45 lesions. Hysteroscopy was then performed in those with identified lesions. Forty-one of the 45 with lesions had a negative aspiration endometrial biopsy; of the 5 (11%) that were diagnosed as malignant lesions, 3 had false-negative biopsies. The combination of endometrial biopsy and sonohysterography had a sensitivity of 97%; a specificity of 70.2%; a PPV of 82.1%; and a NPV of 94.3%.

Epstein et al. prospectively compared TVS, sonohysterography and hysteroscopy in women with abnormal bleeding and endometrial thickness >5 mm [87]. They concluded that saline infusion was as good as hysteroscopy (96%) for the detection of focally growing lesions, but neither modality was able to reliably discriminate between benign and malignant focal lesions. These studies suggest that sonohysterography should be included in the evaluation of the woman with abnormal bleeding. In addition, Neele et al. found 37% and Cohen et al. found 36.8% of asymptomatic postmenopausal women to have endometrial pathology using sonohysterography [85,88]. Some have even suggested routine screening of all asymptomatic women with sonohysterography [89,90].

Cohen et al. placed postmenopausal women with asymptomatic endometrial pathology detected by sonohysterography on cyclical hormone replacement therapy and monitored bleeding patterns [87]. Three of 7 patients (43%) with submucosal pathology had abnormal bleeding, while 1 of 28 patients (3.6%) with a normal cavity had abnormal bleeding at 3 months (p<0.05). Identifying such pathology potentially may serve as an important tool: 1) for future study of potential medical treatment or prevention; 2) recommending therapy for women; and 3) perhaps improving hormone treatment compliance.

In those patients where endometrial cancer is identified, it would be extremely helpful to the general gynecologist to have the ability to predict the presence and extent of myometrial invasion in these patients. This would allow more appropriate triage to gynecologic oncologists. Histology, tumor grade, depth of myometrial invasion, and tumor size are well known prognostic factors for lymph node metastasis but have been difficult to predict preoperatively [91]. MRI is effective in predicting the depth of myometrial invasion and tumor size, but this test may not be cost-effective and is not universally available [92].

Sonohysterography may have the ability to distinguish malignant from benign endometrial abnormalities and has been evaluated for predicting the depth of myometrial invasion. On TVS, endometrial carcinoma can be
described as diffusely or partially echogenic. Following sonohysterography, endometrial carcinoma has been described as irregularly thickened endometrium, mass-like, but indistinguishable from endometrial hyperplasia [93]. Others have described a poorly distensible endometrial cavity as a potential sign of endometrial cancer [94]. The added use of Doppler ultrasound scanning to assess blood flow impedance (resistive index or pulsatility index) does not appear to add any further information, with respect to histopathologic type of the polyp (nonfunctional, proliferative, secretory, hyperplastic or malignant) [95] (Figure 23).

![Figure 23: Polyps on Doppler SIS.](image)

The accuracy of sonohysterography in the early diagnosis and detection of myometrial invasion has been reported by Valenzano et al [91]. Sonohysterography was performed in 19 patients with a histologic diagnosis of endometrial adenocarcinoma obtained by hysteroscopy and biopsy. The number and size of lesions and the degree and depth of myometrial infiltration was assessed. A single lesion was seen in 15 patients (79%) and multiple lesions were seen in four (21%). The sensitivity was 86%, the specificity was 100%, positive predictive value was 100% and negative predictive value was 91%. The presence of myometrial invasion was correctly evaluated in 17 (89%) women. Sonohysterography allowed exact depth of myometrial invasion in 15 cases (94%). A more recent study examined the preoperative and definitive grading and myometrial infiltration detected by ultrasonography and gross examination of 75 patients with International Federation of Gynecology and Obstetrics stage I endometrial cancer [96]. The study showed TVS had diagnostic accuracy of 73%, whereas gross examination correctly determined myometrial invasion in 82.6% of the patients, with sensitivity of 62% and specificity of 79%. These results suggest a possible role of sonohysterography in preoperative staging of endometrial carcinoma and warrants further evaluation.

Some concerns have been raised regarding the possibility of flushing of malignant endometrial cells into the peritoneal cavity during procedures such as hysteroscopy, hysterosalpingography and sonohysterography. Studies have shown that lymphatic and venous intravasation of contrast medium does not alter 5-year survival rates in
patients with endometrial cancer [31]. In a study done by Alcazar et al. 14 patients diagnosed with Stage I endometrial carcinoma and scheduled for surgical staging underwent sonohysterography at the time of laparotomy with 10-20 mL of saline infused at the time of sonohysterography [97]. All fluid that spilled from the fallopian tubes was collected and analyzed for the presence or absence of malignant endometrial cells. In nine patients, there was no spillage from either tube. In the other five patients, a mean volume of 4.4 mL was obtained. In one case (7%), malignant cells in the spilled fluid were present. The prognostic significance of endometrial cancer cells in the peritoneum is controversial, yet a small risk of cancer dissemination may exist. The volume instilled was 10 to 20 mL in Alcazar’s report and perhaps smaller volumes, resulting in less fluid extravasation, would further minimize the risk of dissemination.

In a study by Berry et al. sonohysterography was performed at laparotomy on 16 patients with endometrial adenocarcinoma [98]. With this diagnostic tool, the median volume that was required for adequate visualization was 8.5 mL. Five of the patients (31%) had transtubal spill, and with an additional saline solution flush, the median total volume for a spill was 20.5 mL. Two patients (12.5%) had viable benign cells that were cultured after routine sonohysterography, while nonviable carcinoma cells were identified in one patient (6%). Thus, it is evident that transtubal spill occurs during sonohysterography, but no critical spill volume was identified. This indicates that sonohysterography has a low probability of cancer cell dissemination [97].

For women with estrogen-receptor-positive breast cancer, the benefits of tamoxifen as adjunctive therapy with respect to recurrence and prevention have been clearly established. However, while tamoxifen acts as an estrogen antagonist in breast, it can have agonistic activity in the genital tract, causing endometrial hyperplasia and neoplasia. Published reports reveal a 27% incidence of polyp formation, a 9% incidence of proliferation or hyperplasia, and a rate of endometrial cancer that is two to three times higher than that of an age-matched population [99,100]. The American College of Obstetricians and Gynecologists has developed recommendations based on tamoxifen's effect on the endometrium [101]. These include: 1) monitoring for symptoms of endometrial hyperplasia or cancer; and 2) unless the patient has been identified to be at high risk of endometrial cancer, routine surveillance has not proven to be effective and is not recommended.

Using TVS as a screening tool in women using tamoxifen for abnormal endometrial proliferation or endometrial cancer has not been shown to be effective [102]. There is a poor correlation between ultrasonographic measurements of endometrial thickness and abnormal pathology because of tamoxifen-induced subepithelial stromal hypertrophy [100]. Conversely to TVS, SHG appears to be far more useful in tamoxifen treated patients (Figure 24). In symptomatic women receiving tamoxifen, sonohysterograms (n=38) were compared with endometrial biopsies
and then followed by hysteroscopy [103]. Sixty-three percent of sonohysterograms with normal endometrial biopsy (n=19) had detected abnormalities. Moreover, surgery was avoided in 14% of cases of sonohysterography, which revealed normal endometria or subendothelial cysts. Sonohysterography may prove useful in helping to delineate hyperplastic conditions in those women symptomatic when taking tamoxifen, while in the asymptomatic patient, sonohysterography has appeared to add little value.

Figure 24: Effect of tamoxifen on the endometrium.

Uterine Pathology

Uterine fibroids or leiomyomas are the most common benign tumor of the female genital tract, affecting 20% to 40% of women of reproductive age [104]. These tumors, which fluctuate in size depending on pregnancy, menopause and medical suppression using GnRH-agonists, can cause pelvic pain, abnormal bleeding, subfertility and pregnancy wastage. Ultrasound can localize fibroids as submucosal, intramural or subserosal. Fibroids typically appear as well-circumscribed, hypoechoic masses (Figure 25). They usually contain calcium or rarely fat and often undergo cystic degeneration and develop cystic or hemorrhagic areas. Small submucosal fibroids can cause focal hypoechoic indentation on the endometrial stripe.

Figure 25: Submucosal fibroid.

Pedunculated fibroids can be confused with solid adnexal masses, but identification of both ovaries as separate
from the mass will usually help establish a correct diagnosis. In difficult cases, Doppler color ultrasound has been described to be useful as it may identify a feeding blood vessel that arises from the uterus [105] (Figure 26).

![Figure 26: Fibroids on Doppler.](image)

Identifying the size, location, and depth of myometrial involvement of submucosal uterine leiomyomata is a determinant for a successful surgical outcome. In a comparison study of 52 women scheduled for hysterectomy due to leiomyoma, Cicinelli et al. compared the accuracy of TVS, sonohysterography and hysteroscopy in detecting the size of the submucosal components of leiomyoma [106]. Sonohysterography was the most accurate in this study, demonstrating that the size and location of uterine leiomyomata can be determined accurately. A more recent study has substantiated that sonohysterography is a better tool than transvaginal sonography for the assessment of endometrial intracavitary lesions [107]. This information will help predict the resectability of these tumors, the number of surgical procedures necessary for complete resection, the duration of surgery, and the potential for complications related to fluid overload.

In comparison, adenomyosis is the presence of ectopic endometrial glands in the myometrium that are surrounded by hypertrophied smooth muscle, and has been detected in 8 to 30% of hysterectomy specimens [108]. It typically affects the uterus in a diffuse manner, but when focal disease is present, adenomyomas result. Ultrasound imaging can reveal diffuse uterine enlargement without focal abnormality, diffuse posterior myometrial thickening and myometrial sonolucencies [109].

### Adnexal Pathology

Ovarian pathology, including dermoid cysts and endometrioma(s) can easily be seen on TVS/TAS. Dermoid cysts can have many appearances including completely cystic in appearance to a complex mass with solid elements that appear as hyperechogenic. These occur from hair and fatty material within the dermoid. Endometriomas typically have homogeneous low-level echoes which is present in 82% to 93% of those confirmed at laparoscopy [110]. Less frequently seen are septations (29% of
patients) and fluid levels (5%), though these findings can be seen with hemorrhagic corpus luteum, ovarian abscess, dermoid, cystadenoma and carcinoma(s) [111]. However, these ultrasound findings are not pathognomonic for endometriomas.

TVS can also detect tubal dilation that appears as a fluid-filled structure that may look like a pear-shaped or ovoid structure containing various degrees of low-level echos, which can be interpreted as free or loculated cul-de-sac fluid collection (Figure 27). This is often a late sign of chronic tubal salpingitis [112]. Incomplete septa can be seen on longitudinal or transverse section and may be the result of the wall of the tube folding on itself [113].

Infertility Evaluation

It has been estimated that congenital and acquired uterine pathology is present in up to 10% of infertile couples and 15% to 55% of those with recurrent pregnancy loss, including müllerian and DES-related anomalies, uterine fibroids, endometrial polyps and Asherman’s syndrome [114]. Moreover, difficult intrauterine inseminations or embryo transfers secondary to cervical pathology adversely affect outcomes in women undergoing assisted reproduction [115]. Abnormalities related to the uterus or fallopian tubes (pelvic factors) are seen in 30% and 40%, respectively, of infertile women [116]. For the infertile patient, HSG is the first line of evaluation and laparoscopy and hysteroscopy are reserved for times when all other diagnostic testing is normal or when there is reason to suspect intra-abdominal pathology (endometriosis, pelvic adhesions, uterine fibroids). However, in more recent investigations the value of sonohysterography in the evaluation of the infertile female has been explored.

The use of sonohysterography prior to undergoing assisted reproduction has been evaluated and compared to traditional HSG or hysteroscopy. Kim et al. reported results in 72 infertile women who underwent sonohysterography for uterine screening prior to undergoing in vitro fertilization [117]. Eleven percent had cavitary lesions and there was no statistical difference in pregnancy outcome compared to those who had HSG or hysteroscopy for uterine evaluation [117]. Lindheim et al. have reported pre-screening sonohysterography in those undergoing...
ovum donation and found pathology in 38% of women studied and confirmed at hysteroscopy [118]. Many now incorporate sonohysterography as the first-line screening for the evaluation of the uterus before embryo transfer in patients undergoing IVF, ovum donation, and IVF-surr-
gagy [119].

Patients with acquired uterine hypoplasia due to drugs, pelvic irradiation, or ovarian failure may have a disproportionately small uterine corpus where the ratio of the uterine body to the cervix is reduced to less than the normal 2:1 [120]. Sonography has been used to evaluate müllerian duct anomalies, which represent a wide spec-
trum of abnormalities resulting from failure of development, fusion and/or resorption of the paired müllerian ducts. This has been reported in up to 5% of the general population with the most anomalies being arcuate, sep-
tate, and bicornuate uteri [121]. Coronal imaging of the uterine fundal and endometrial contour is critical in the diagnosis. However, unlike endometrial adhesions or polyps where it is important to perform the ultrasound at the appropriate time of the menstrual cycle, the timing for evaluation of uterine anomalies is not essential [122]. Splitting of the endometrial echo by a hypoecho-
genic band is typically seen. A fibrous septum can be sug-
gested when its echotexture is less than myometrial tissue, whereas muscular septal tissue is suggested when the sep-
tum is isochoic to myometrial echoes [121] (Figure 28), in comparison, fundal notching can be seen to differentiate the bicornuate uterus (Figure 29) [25]. However, refrac-
tive shadowing limits the ability of sonography to distin-
guish between fibrous and myometrial tissue, thus MRI is the preferred modality for diagnosis.

Figure 28: Septate Uterus.

Figure 29: Bicornuate Uterus.
Endometrial thickness and endometrial pattern seen on TVS have been advocated as markers for ART outcomes. Decreased pregnancy and implantation rates and higher miscarriage rates have been reported in those with a thin endometrium (<6 mm) compared to a thick endometrium (>6 mm) [118,119], though others have reported no predictive value in this measurement [123]. An endometrial pattern that is hyperechogenic (non-triple layer), which is unrelated to endometrial thickness appears to have good predictive value in a review of 13 studies, though a poor endometrial pattern does not exclude the possibility of pregnancy [124]. Visualization of defects with TVS or HSG provides a foundation on which to begin IVF treatment.

Anatomic disorders, including congenital müllerian anomalies and acquired defects such as uterine leiomyomata and uterine synechiae (Figure 30), account for 15% to 55% of recurrent pregnancy loss [93]. The diagnosis and surgical correction of uterine defects associated with recurrent pregnancy loss increases the rate of full-term delivery [125]. Traditionally, hysterosalpingogram has been the diagnostic test of choice for uterine anomalies. However it has clear limitations in assessing the outer uterine contour, and in many cases, has limited ability to discriminate between septate and bicornuate uterus [126,127].

TVS has been used to diagnose müllerian anomalies as previously discussed. Sonographic criteria have been established to differentiate bicornuate uterus from septal defects, including fundal broadening, diverging endome-
Hysterosalpingo-Contrast Sonography (HyCoSy)

Hysterosalpingo-contrast sonography, known as HyCoSy, is a procedure involving the injection of an echo-enhancing agent, usually an agitated saline-air mixture into the uterus and fallopian tubes. A transvaginal ultrasound is then performed in order to assess tubal patency. A normal fallopian tube is not visible using only ultrasound technology. The introduction of air bubbles into the uterine cavity allows a more accurate picture of tubal anatomy.

The clinical indication for HyCoSy is mainly for the evaluation of fallopian tubes and the uterine cavity as part of the infertility workup. Abnormalities related to the fallopian tubes account for up to 40% of female subfertility [130]. While laparoscopy is still considered the gold standard and HSG a complement to laparoscopy in the diagnostic evaluation of fallopian tubes, there has been a move away from these methods. HSG obviates the need for hysteroscopy and/or laparoscopy, but it is associated with exposure to ionizing radiation and the need for iodinated contrast material [131]. Importantly, HyCoSy appears to be as accurate as the HSG when compared to laparoscopy with a diagnostic accuracy of 65% to 85% in establishing tubal patency [132].

Figure 31: Air insufflation.

HyCoSy has thus increasingly been reported since the 1980s to assess tubal patency. However, its use in evaluating tubal patency has been limited as the normal fallopian tube reflects ultrasound poorly and lacks the defined interfaces that produce clear organ outlines [14]. To enhance TVS visualization of tubal anatomy, a number of contrast agents have been employed. Some clinicians have substituted a mixture of saline and/or air for more elaborate distending media (Figure 31). Some vigorously shake a syringe of saline and air creating air bubbles immediately before infusion, while others have described filling a syringe with both air and saline and tilting the syringe to allow the intermittent infusion of air followed by sa-
line in increments of 1–3 mL [133,134]. Recently, the FDA approved a saline-air device, which creates and delivers a constant alternating pattern of filtered saline and air as a continuous stream in a controlled fashion allowing for fallopian tube evaluation under ultrasound guidance [135].

The low cost of air and saline solutions makes this particular HyCoSy procedure attractive to determine tubal patency. When compared to both laparoscopy and HSG, the positive and negative predictive values for air contrast HyCoSy have been reported to be similar to other contrast materials for both tubal patency and occlusion. In cases of non-visualization, attempts to combine Doppler flow to improve the demonstration of the tube might prove beneficial but this adds another layer of ultrasound complexity [136].

Unlike the distinct tubal anatomy seen with the HSG, tubal architecture cannot be discerned with ultrasound unless a hydrosalpinx is present. An additional challenge of air bubbles is that they disappear from view quickly since the fallopian tube is not linear and lies in different planes. Therefore, the ultrasonographer must be skilled, making rapid movements of the probe to visualize the entire tubal course during the brief infusion. The requirement of this advanced skill level may limit tubal assessment, especially in distinguishing the tubal lumen from air moving in the bowel. To help with this challenge, the HyCoSy-saline-air device creates and infuses a controlled, constant alternating pattern of saline and air as a continuous stream. The air also goes through a micro-filter within the device eliminating any risk for bacterial infection, though the risk of insufflation of bacteria with the room air is considered small.

The HyCoSy-saline-air device has good predictive value in the case of tubal patency and may be considered the first-step procedure in the assessment of tubal patency in patients with minimal risk factors. The advantage of HyCoSy-saline-air device is that it is a relatively quick and non-invasive procedure that may be performed in the office setting, and does not require exposure to ionizing radiation. Several studies have demonstrated concordance rates of 83% to 100% between HyCoSy-saline-air device, laparoscopy and HSG when detecting tubal pathology [137-139].

**Other Diagnostic and Therapeutic Applications of Sonohysterography**

Sonohysterography may be of benefit to women who give a history of a “lost” IUD or when a string cannot be visualized and may be helpful for locating the IUD and determining whether the IUD is embedded in the myometrium (Figure 32) [140]. Others have described case reports on the use of sonohysterography to document and remove fragments of laminaria from the uterine cavity, diagnosing post-abortal remnants including placenta accreta and previous cesarean delivery scars [141,142].
Coccia et al. coined the term PLUG (Pressure Lavage Under Ultrasound Guidance), for the treatment of selected cases of intrauterine adhesions [143]. In their small descriptive report, seven patients were evaluated for secondary amenorrhea due to intrauterine adhesions. The effect of continuous accumulation of saline for the mechanical disruption of intrauterine adhesions was assessed. Five patients with mild adhesions had satisfactory lysis of adhesions by the use of the PLUG technique, while two patients with moderate adhesions had persistent disease at second-look hysteroscopy. Restoration of menses was achieved and had continued in all seven patients and two of the three infertile patients became pregnant. For mild disease, these authors suggest that PLUG may have a primary therapeutic role. In cases of moderate disease, PLUG may have some limited value in reducing the need for operative hysteroscopy. Further investigation using a control group is warranted.

The use of ultrasonography as an intraoperative aid has been well described. Such uses include assurance of complete removal of products of conception, removal of impacted foreign bodies, and correct placement of the intrauterine tandem apparatus for intracavitary radiation [144-146]. More recently, reports of intraoperative sonohysterography have been utilized as an adjunct to operative hysteroscopy and laparotomy [147]. This use of sonohysterography is to assure complete removal of deep intramural myomas abutting the endometrial cavity, to provide reassurance during intrauterine resection and to clarify confusing findings.

Successful therapeutic intervention with ultrasound for directed biopsies for submucosal pathology has been demonstrated [148]. In earlier work, the directed biopsies utilized a 3-FR loop or finger-like grasper inserted through an access catheter. However, the instrument’s application was restricted by its small size and limited rotation [21]. Alternatively, resection of intrauterine abnormalities using a loop snare under transvaginal ultrasound has been successfully applied [149]. Access to the uterine cavity is accomplished with a 12-FR intrauterine access catheter with a 3-mL balloon (Cook OB/GYN) which is placed in
the cervical canal. A 5-FR echogenic loop snare is then passed through the access catheter with resection. Limitations include cervical stenosis, precluding placement of the operative instruments, and cornual lesions, which are difficult to adequately resect. Nevertheless this may represent a cost-effective alternative to hysteroscopy and deserves further study [150].

Endometrial sampling of intrauterine pathology can be achieved through use of a SonoSure™ device (CrossBay Medical Inc., San Francisco, CA) during SIS, especially in patients with abnormal uterine bleeding or heavy menstrual periods [151]. With the use of a traditional catheter, the inflated balloon obscures a portion of the uterus (Figure 33).

SonoSure™ uses a cervical sealing mechanism to avoid masking the lower uterine segment, thus providing a complete view of the uterine cavity during sampling. Used as a complement to SIS, this method has been proved effective for pelvic imaging and simultaneous sampling in women with abnormal uterine bleeding [152].

**Conclusion**

Pelvic sonography, sonohysterography, and Hystero-Contrast Sonography have proven to have enormous value in the investigation of gynecologic disorders including abnormal uterine bleeding and infertility. These are simple and inexpensive procedures that add tremendously to our diagnostic acumen and should be considered as part of the routine assessment of the reproductive tract.

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