Laparoscopic Intraoperative Ultrasonography

DUNCAN J. TURNER, M.D., M.B., B.S., F.A.C.O.G.
DIRECTOR OF SANTA BARBARA OBSTETRICS AND GYNECOLOGY ASSOCIATES
DEPARTMENT OF GYNECOLOGY, SANTA BARBARA COTTAGE HOSPITAL
DEPARTMENT OF GYNECOLOGY, DE LA VINA SURGICENTER
SANTA BARBARA, CALIFORNIA

Ultrasonography has been an integral part of gynecology and general surgery in recent years. New technology has allowed this modality to be extended to include intraoperative assessment through a laparoscopic approach. This allows more accurate imaging with higher resolution than previously attainable. Combining the ultrasonic and visual images on the monitor screen simultaneously (picture in a picture) allows a further dimension of information which can modify surgical direction. The equipment used by the author is described and clinical experience discussed. Further clinical applications are considered and the practicality of the methodology assessed.

It is unlikely that any field has been advanced more by ultrasonography than obstetrics and gynecology. Since the first real-time images some 25 years ago, ultrasonography has aided and directed diagnosis to an ever increasing degree. It is unusual for a patient to give birth without at least one ultrasound scan during the course of the pregnancy and often scans are multiple. It is also unusual for any patient to undergo gynecological surgery without preoperative ultrasound assessment. The modality was enhanced significantly with the arrival of the vaginal ultrasound probe 10 years ago. Most gynecologists have access to this in their offices and clinics. We have come to rely on this modality in as great a way as we rely on physical examination and, although armed with this information upon arriving in the operating room, the modality has not been easily accessible intraoperatively until recently. It has been thought that the availability of intraoperative ultrasound would improve the accuracy of diagnosis.[1] The development of laparoscopic probes now makes this possible. In addition, Doppler technology, needle biopsy guides, and digital video mixing to incorporate both visual and ultrasound images on the screen simultaneously have added to convenience and accuracy.

ULTRASOUND

Ultrasound, by definition, is sound beyond the ability of the human ear to perceive. It is high frequency sound waves that exceed 20,000 cycles per second. Measured as hertz (Hz), the frequency refers to the number of waves that pass a given point per unit of time. Commonly, the transducers used in diagnostic ultrasonography operate at frequencies of 2 million to 10 million Hz, or 2 to 10 megahertz (MHz). High resolution of image is achieved with higher frequency, but penetration of tissue is lower. The reverse is true for lower frequencies. It is therefore necessary for different probes to be utilized in different clinical applications. Abdominal ultrasound probes are usually in the range of 3.5 to 5 MHz while most transvaginal probes operate at 5 to 7.5 MHz. Laparoscopic probes, although only recently available, have utilized 7.5 to 10.0 MHz.

Transducers have been designed in a number of different formats. There is a linear array in which a longitudinal series of transducer crystals are arranged in sequence and also an annular array scanner that has serial transducers arranged in concentric rings. A sector scanner incorporates a single transducer that moves through a prescribed arc, usually 90 degrees. Curvilinear transducers incorporate principals of both linear and sector methods. The system utilized by this author is a sector scanner which is geometrically moveable over 90 degrees within

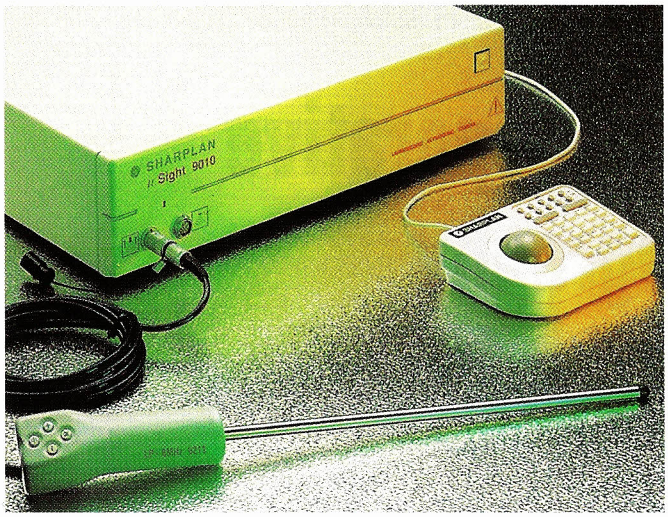

Figure 1. Ultrasound system with 10-mm laparoscopic probe.

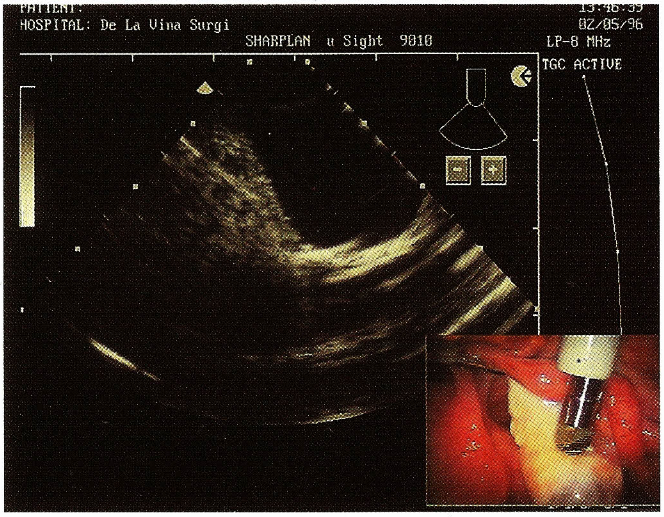

Figure 2. Delineation of ovarian cyst from normal ovarian tissue aiding surgery.

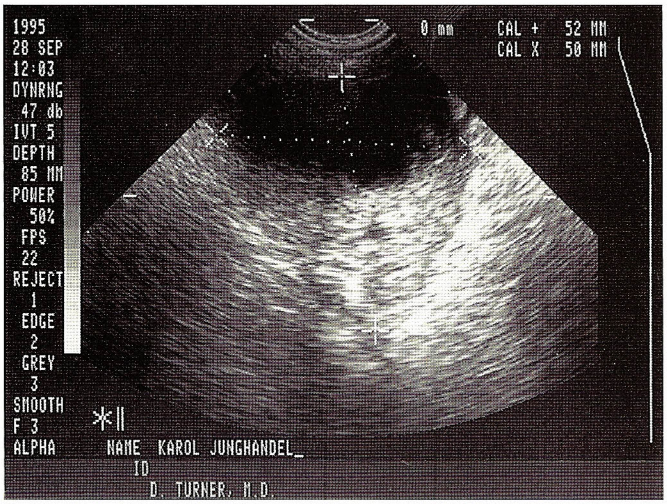

Figure 3a. Right adnexal mass described by radiologist as an enlarged right ovary with multiple follicular cysts. Pelvic mass appears benign in preoperative examination.

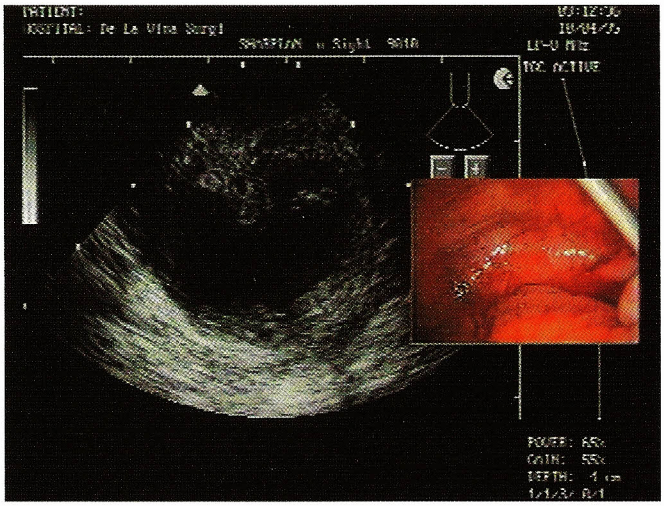

Figure 3b. Intraoperative assessment—more ominous.

Figure 4 (a, b). Examination of different depths of the liver reveals involvement of the peritoneal surface only in this case of pseudo-myxoma peritonei.

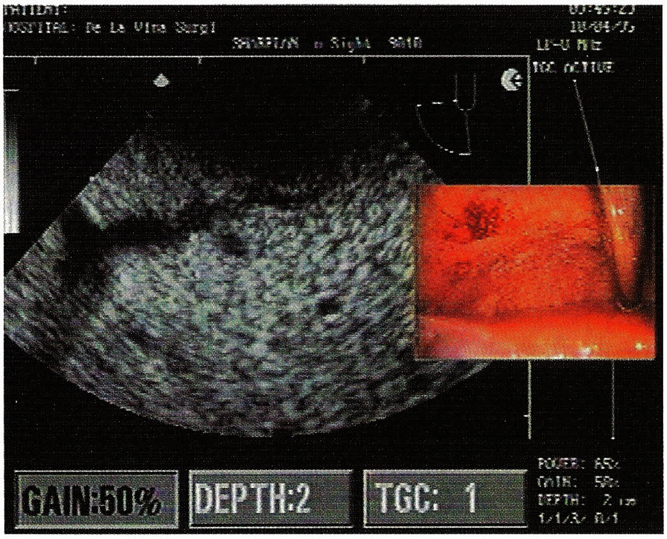

Figure 4a.

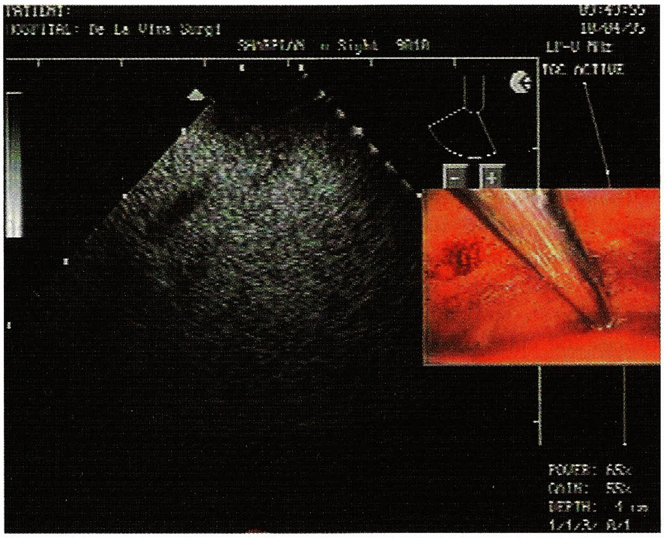

Figure 4b.

the probe so that a field of 180 degrees can be evaluated without moving the probe (Fig. 1).

Although ultrasound at high power can be destructive and is utilized as such, for example, in physical therapy and urology, no problems have been associated with diagnostic ultrasound and there are many in vitro and animal studies to confirm this.[2-9]

MATERIALS AND METHODS

The laparoscopic ultrasound system utilized is a Sharplan u Sight 9010 used in conjunction with a Sharplan i Sight 8010 camera and bi Sight digital video mixer (Sharplan Lasers, Inc., Allendale, N.J.).

The Sharplan u Sight 9010 is a real-time 2-dimensional mechanical sector scanning diagnostic ultrasound system. A variety of probes are available including 10-mm laparoscopic probes of either 8 MHz or 10 MHz, intraoperative abdominal probe of 10 MHz, general abdominal probe of 3.5 MHz, transvaginal probe of 6.5 MHz, and transrectal probe of 6.5 MHz. Only the laparoscopic 8 MHz probe is described in this report.

The system consists of the ultrasound control unit which controls the energy transmitted to and from the probe and processes the signals to display real-time images. A keyboard with track ball allows for control of the system and the laparoscopic probe utilized is 10 mm in diameter and can be passed through a 10-mm laparoscopic cannula (Fig. 1). The 90-degree sector scanner is maneuverable within 180-degree field of view and remote control is accessible on the handle of the probe and includes image freezing, programming changes in depth, gain and TGC, and direction of the sector scanner. A high resolution monitor is required to display the image. The probe is sterilized by soaking, as is the cord.

The i Sight is a single chip digital endoscopic camera which has pixel-by-pixel sensitivity control enabling real-time visualization of both bright and dark areas. It features edge enhancement, high resolution and also a fuzzy-logic automatic shutter and shutter speed. Remote control operation is possible and there is extended zoom range. The camera head weighs 4.6 ounces and can be sterilized by soaking. The minimum sensitivity is 3 lux at f 1.2. The zoom is f 20-45 and the signal to noise ratio is better than 55 db. The image processing technology essentially reduces the overexposed areas to eliminate glare, brightens the dark areas to improve visibility and enhances details to create sharp images. The picture occasionally appears somewhat grainy at dark areas but, when compared to other cameras, appears to illuminate more of the field.

The bi Sight digital video mixer allows simultaneous ultrasound and video image on the screen at any time in variable sizes and reversible bias. Digital stores of several hundred images with full data management are also built in and image retrieval is simple and quick. The bi Sight system is controlled from the front panel of the mixer and requires a circulating nurse to operate if the surgeon is scrubbed.

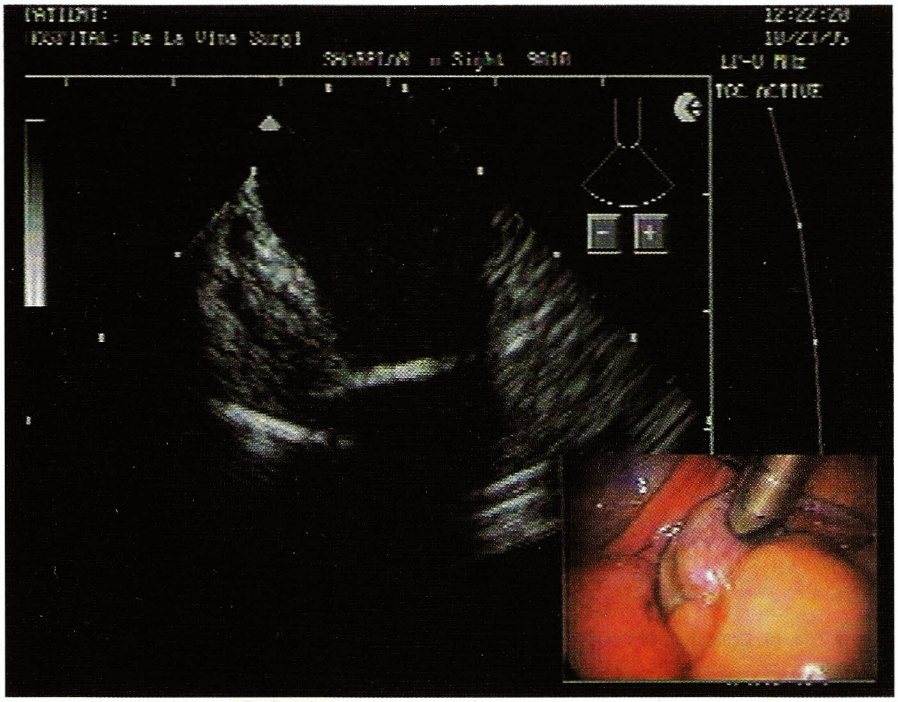

Figure 5. Seventy-year-old patient with adnexal mass. Intraoperative ultrasound reveals fluid rather than solid tubal enlargement.

CLINICAL EXPERIENCE

Evaluation of the clinical applications of the modality was performed by having the equipment available in all cases of laparoscopic surgery. Ureters, vessels and organs were all examined whenever possible.

In cases of ovarian cysts, it is possible to clearly delineate the margins of the cyst, thus enabling more accurate cystectomy (Fig. 2). In another circumstance, a pelvic mass previously looking benign on transvaginal ultrasound (Fig. 3a), in the opinion of the radiologist had much more ominous findings intraoperatively (Fig. 3b). In the same case, which turned out to be pseudomyxoma peritonei, an implantation on the liver was evaluated showing only peritoneal involvement (Fig. 4).

In the case of a 70-year-old patient with an adnexal mass, laparoscopic findings were of bilateral hydrosalpinges. Without a history of pelvic inflammatory disease, it was possible to see that these were indeed hydrosalpinges and did not involve a solid tumor, allowing for safer surgery (Fig. 5).

In a case of tubo-ovarian abscess formation suspected, but not confirmed prior to surgery, the intraoperative ultrasound findings were helpful as the mass was largely retroperitoneal and dissected anteriorly between the bladder and the lower segment of the uterus. Surgery, ultimately a hysterectomy and bilateral salpingoophorectomy, was performed more easily (Fig. 6).

Other incidental advantages included a greater ability to evaluate the abdomen than with laparoscopy alone. It is routine in abdominal surgery to explore the abdomen by palpation. This is not possible laparoscopically but now with ultrasound the gallbladder, liver, bladder (Fig. 7), and kidneys can be quickly and easily evaluated and margins delineated.

Hysteroscopic surgery can be aided by this modality as with extensive lysis of intrauterine adhesions or removal of myomas or septae. The instruments can clearly be seen by simultaneous

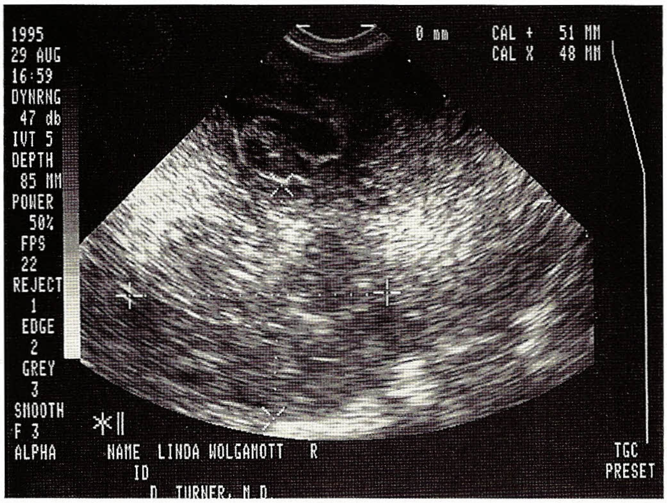

Figure 6a. Right-sided pelvic mass adjacent to uterus appears homogenous on transvaginal ultrasound.

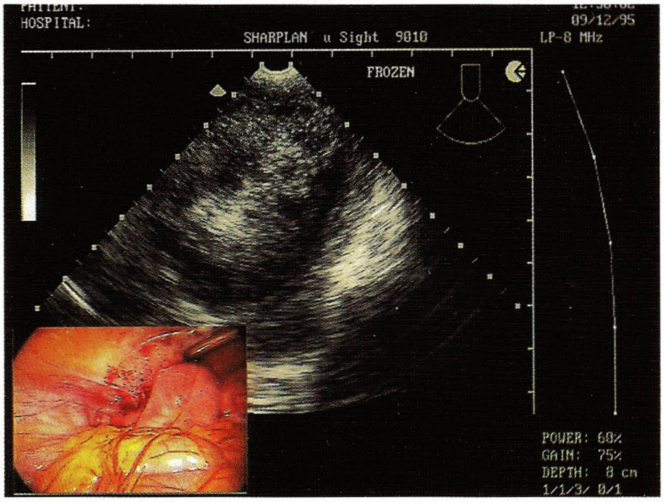

Figure 6b. Intraoperative ultrasound shows heterogenicity more clearly.

Figure 7 (a, b). Evaluation of the gallbladder with either ultrasound-dominant (7a) or visual-dominant (7b) images.

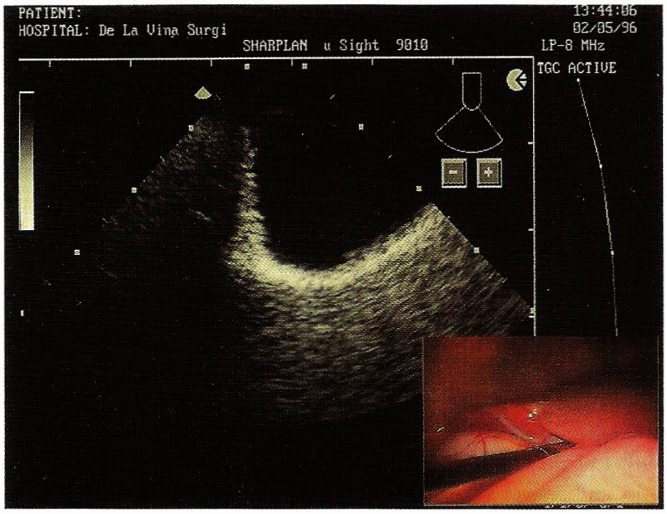

Figure 7a.

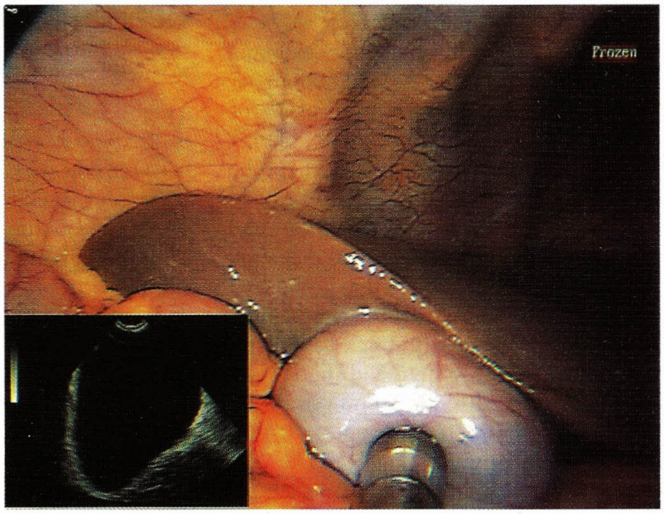

Figure 7b.

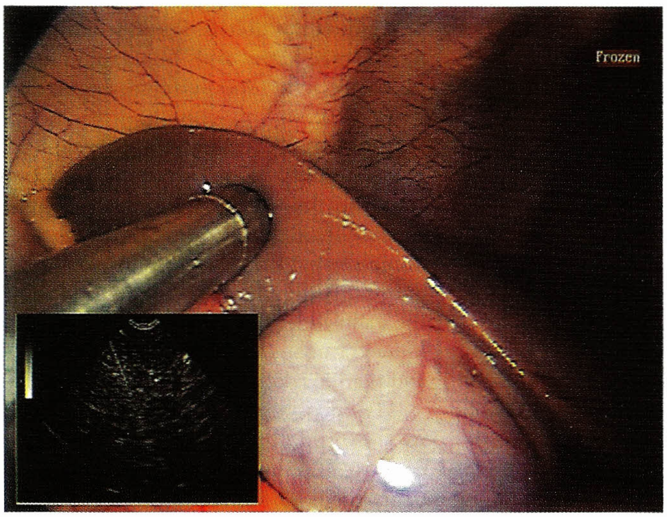

Figure 7c. Assessment of the liver parenchyma by direct contact ultrasound.

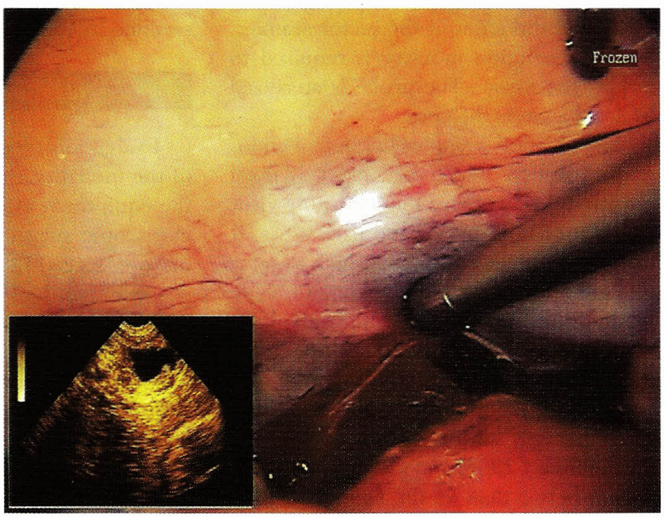

Figure 7d. Delineation of the bladder at the time of laparoscopic surgery.

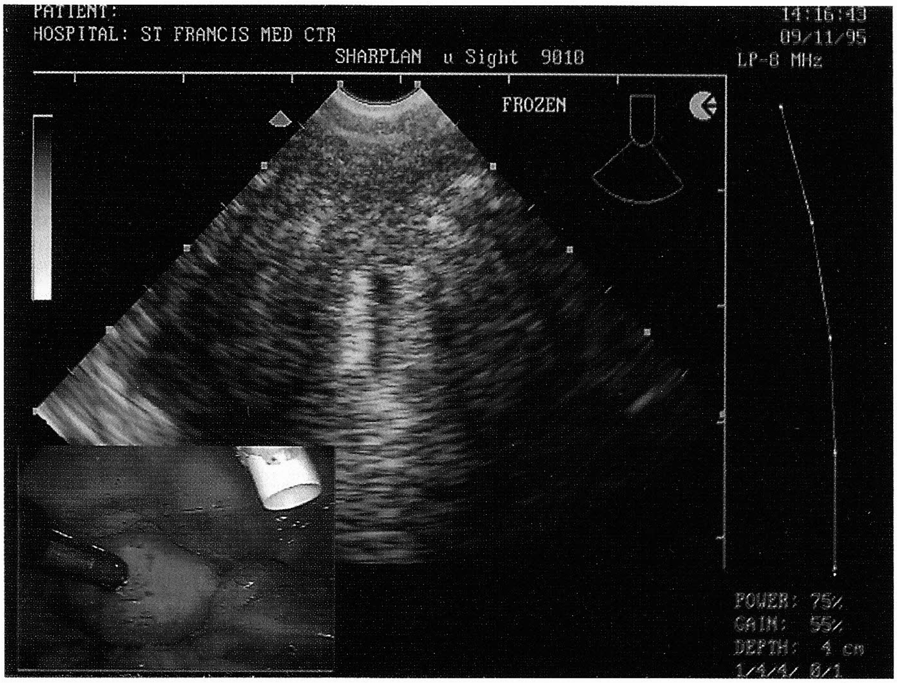

Figure 8. Evaluation of hysteroscopic procedure.

laparoscopic ultrasound thus diminishing the chance of uterine perforation present when using other monitoring methods (Fig. 8).

DISCUSSION

The accuracy of ultrasound is diminished by the distortion of sound waves passing through intervening tissue, which varies tremendously from person to person and organ to organ.[10] When compared to laparoscopic evaluation, ultrasound extracorporeally has been shown to be inferior.[28] With intraoperative ultrasound, the closeness of the organ to be examined and the frequency of the scan head can be extremely high and consequently resolution is superior.[1] It is also possible to "see" beyond the line of sight; for example, in the presence of intra-abdominal adhesions the sound waves may obtain an image beyond the adhesion enabling safer and more accurate surgery.[1]

One of the disadvantages of laparoscopic surgery is the lack of the surgeon's ability to palpate tissue. Intraoperative ultrasound may be a substitute for this[11] and has been described as indispensable.[12]

Most of the literature relative to intra-abdominal laparoscopic ultrasound relates to general surgery and oncology. It has been shown to be beneficial in the evaluation and staging of tumors of the pancreas,[13,14] esophagus,[15] colorectal and liver.[12,13,15,17-22,24,25] Surgical staging has been enhanced.[17-19] Biopsies have been enabled more accurately and safely[10,20-22] and accuracy of surgical excision improved.[18,23] In renal transplantation the postoperative complication of lymphocele can be addressed by ultrasound-guided laparoscopic drainage.[16]

In gynecology ovarian masses have been evaluated more accurately with intraoperative ultrasound finding information in addition to that acquired preoperatively by ultrasound in a high percentage of cases.[1] In fact, additional information has been gleaned with this modality in many studies.[15,24-28]

It is a common and appropriate practice for relevant X-rays to be taken to the operating room for evaluation by the surgeon at the time of surgery. Ultrasound is more difficult to evaluate in such a manner as the points of reference change depending upon the angle and position of the transducer. It is not always practical to take more traditional ultrasound equipment into the operating room with both an ultrasonographer and radiologist. Therefore, if the surgeon can adequately evaluate ultrasound images him or herself and control the image obtained, this should remove the obstacles of inconvenience in achieving more information.

Most gynecologists are adept at vaginal probe ultrasound evaluation. Most often, the same structures can be evaluated intra-abdominally with less distortion of intervening tissue. There is certainly a learning curve involved for those unfamiliar with ultrasound[29] and training methods have been suggested for those unfamiliar with the modality.[30]

The laparoscopic probe utilized in this report involves a moveable sector scanner which improves ease of use. As opposed to linear scanners which obtain and image at right angles to the direction of the probe, the sector scanner "looks right ahead" and can be adjusted anteriorly or posteriorly as previously mentioned. Although not available to this author, Doppler imaging is available with this equipment and may be helpful in evaluation of vasculature. A needle biopsy guide was available but not evaluated.

CONCLUSIONS

Laparoscopic ultrasound offers an extension of a previously well established modality into the operating room. The equipment described provides ease of use and convenience which previously has been unavailable. The part that this will play in laparoscopic surgery remains to be seen but there are distinct advantages in improving accuracy of diagnosis and therapy, with little additional operative time or training necessary on the part of the surgeon. This is user-dependent technology and the usefulness of this equipment will be additionally improved as experience increases. STI

REFERENCES

1. Sohn C, Wallwiener D, Grischke EM, et al. Initial experiences with laparoscopic intraoperative ultrasound. Geburtshilfe und Frauenheilkunde 1995;55(8):468-72.
2. American Institute of Ultrasound in Medicine. Bioeffects considerations for the safety of diagnostic ultrasound. J Ultrasound Med 1988;7(suppl 9);S1-38.
3. Sikov MR. Effect of ultrasound on development: I. Introduction and studies in inframammalian species. J Ultrasound Med 1986;5:577.
4. Sikov MR. Effect of ultrasound on development: II. Studies in mammalian species and overview. J. Ultrasound Med 1986;5:561.
5. O'Brien WD. Determination of in situ exposure. Ultrasound Med Biol 1986;12:695.
6. Abraham V, Ziskin MC, Heyner S. Temperature elevation in the rat fetus due to ultrasound exposure. Ultrasound Med Biol 1989;15:443.
7. Tarantal AF, Chu F, O'Brien WD Jr, et al. Measurement of sonographic heat generation in vivo in the gravid long-tailed macaque. J. Ultrasound Med 1993;12:285.
8. Lele PP. Effects of ultrasound in "solid" mammalian tissues and tumors in vivo.

In:Repacholi MH, Grandolofo M, Rindi A. eds. Ultrasound: medical applications, biological effects and hazard potential. New York: Plenum Press; 1987:275.
9. Siddiqi TA, O'Brien WD Jr., Meyer RA, et al. In situ exposimetry: the ovarian ultrasound examination. Ultrasound Med Biol 1991; 17:257.
10. Rau B, Hünerbein M, Schlag PM. Laparoscopic sonography with an ultrasound endoscope. Chirurg 1994;65(4):400-2.
11. Skjoldbye B, Brahe NE, Jess P, et al. Laparoscopic ultrasonography of liver, biliary tract and pancreas with flexible tip transducers. Ugeskrift for Laeger 1995;157(5):580-3.
12. Cavina E, Goletti O, Buccianti P. Echolaparoscopy: an indispensable procedure for laparoscopic surgery. Endoscopic Surgery & Allied Technologies 1994;2(2):143-8.
13. McIntyre RC Jr, Stiegmann GV, Pearlman NW. Update on laparoscopic ultrasonography. Endoscopic Surgery & Allied Technologies 1994;2(2):149-52.
14. Murugiah M, Paterson-Brown S, Windsor JA, et al. Early experience of laparoscopic ultrasonography in the management of pancreatic carcinoma. Surgical Endoscopy 1993;7(3):177-81.
15. Feussner H, Kraemer SJ, Siewert JR. The technique of laparoscopic ultrasound study in diagnostic laparoscopy. Langenbecks Archiv fur Chirurgie 1994;379(4):248-54.
16. Ishitani MB, DeAngelis GA, Sistrom CL, et al. Laparoscopic ultrasound-guided drainage of lymphoceles following renal transplantation. Journal of Laparoendoscopic Surgery 1994;4(1):61-4.
17. Rau B, Hünerbein M, Schlag PM. Laparoscopy and laparoscopic endosonography as staging examination of tumors of upper gastrointestinal tract. Zentralblatt fur Chirurgie 1995;120(5):346-9.
18. Hünerbein M, Rau B, Schlag PM. Laparoscopy and laparoscopic ultrasound for staging of upper gastrointestinal tumors. European Journal of Surgical Oncology 1995;21(1):50-5.
19. John TG, Greig JD, Crosbie JL, et al. Superior staging of liver tumors with laparoscopy and laparoscopic ultrasound. Annals of Surgery 1994;220(6):711-9.
20. Kruskal JB, Kane RA. Intraoperative ultrasonography of the liver. Critical Reviews in Diagnostic Imaging 1995;36(3):175-226.
21. Holscher AH. Invasive ultrasound: value of intraoperative and laparoscopic ultrasound imaging. Bildgebung 1995;62 Suppl 1:39-42.
22. Madsen MR, Mortensen PM, Hovendal CP. Laparoscopic ultrasonography. A review and authors' own experiences. Ugeskrift for Laeger 1995;157(5):575-80.
23. Bezzi M, Merlino R, Orsi F, et al. Laparoscopic ultrasonography in laparoscopic surgery and diagnosis. Radiologia Medica 1995;89(1-2):82-90.
24. Goletti O, Buccianti P, Chiarugi M, et al. Laparoscopic sonography in screening metastases from gastrointestinal cancer: comparative accuracy with traditional procedures. Surgical Laparoscopy and Endoscopy 1995;5(3)-176-82.
25. Weiner R, Winterberg U, Bockhorn H. Laparoscopic staging of gastrointestinal tumors. Zentralblatt fur Chirurgie 1995; 120 (5):350-2.
26. Lirici MM, Caratozzolo M, Urbano V, et al. Laparoscopic ultrasonography: limits and potential of present technologies. Endoscopic Surgery & Allied Technologies 1994;2(2):127-33.
27. Jakimowicz JJ. Technical and clinical aspects of intraoperative ultrasound applicable to laparoscopic ultrasound. Endoscopic Surgery & Allied Technologies 1994;2(2):119-26.
28. Benifla JL, Hauuy JP, Guglielmina JN, et al. Celioscopic removal of cysts: a fortuitous histological discovery of an ovarian carcinoma. A case report. Journal de Gynecologie, Obstetrique et Biologie de la Reproduction 1992;21(1):45-9.
29. John TG, Banting SW, Pye S, et al. Preliminary experience with intracorporeal laparoscopic ultrasonography using a sector scanning probe. A prospective comparison with intraoperative cholangiography in the detection of choledocholithiasis. Surgical Endoscopy 1994;8(10):1176-82.
30. McIntyre RC Jr, Stiegmann GV, Pearlmann NW. Update on laparoscopic ultrasonography. Endoscopic Surgery & Allied Technologies 1994;2(2):149-52.