Foreword

Ultrasonography has evolved from a branch of acoustics that deals with the study and use of sound waves to an important clinical modality in assessing varied structures and organ systems throughout the body. Much of the work began in the 1940s after World War II by examining intracranial abnormalities, and later intrathoracic and intra-abdominal structures. The quality of images gradually improved with the development of gray-scale and real-time imaging, and more recently color and power Doppler studies. Further advancement in minimally ablative technology has utilized ultrasonography to monitor interventional procedures such as renal prostate biopsy and ablative therapy of varied malignancies, in addition to the development of increasing diagnostic appreciations.

Intraoperative ultrasonography has been used by general surgeons in biliary, pancreatic, and vascular surgery and its role in urology is primarily related to the identification of renal calculi at the time of pyelolithotomy or nephrolithotomy. With the development of lithotripsy and percutaneous renal surgery, ultrasound is used in addition to other studies such as computer tomography to identify the location and size of renal and ureteral calculi. For this book, Ukimura and Gill have identified authors having expertise not only in intraoperative ultrasound but also in other applications such as therapeutics and intervention.

Ultrasound has been useful not only in identifying abnormalities such as stones or tumors in kidneys but also in monitoring therapies such as stone removal and renal tumor ablation, in assisting in prostate biopsy, and in studying blood flow to various structures. Applications such as the use of ultrasound contrast agents, elastography, and tissue characterization are evolving and are expected to enhance diagnostic capabilities.

Many of the studies described in this book have proved to be valuable, and the examinations described have become an integral part of interventional and therapeutic applications. Other studies are also evolving, and more application by a large number of investigators is essential to determine their value. It is likely that a second edition of this book will be required to provide an up-to-date compilation of these new developments.

Martin I. Resnick
Hiroki Watanabe
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Chapter 1
Historical Background
Hiroki Watanabe

Prologue

It was a dark evening in the late autumn of 1978. A middle-aged woman was urgently admitted to our hospital in Kyoto because of anuria for a few days. She had suffered from cancer of the right ureter and undergone nephro-ureterectomy. The anuria resulted from an obstruction of the contralateral ureter due to a recurrence of bladder tumor. An immediate catheterization from the left renal pelvis by nephrostomy was indicated.

Even now, senior urologists may remember very well what a dreadful surgery classic open nephrostomy was. The kidney was exposed after a large incision in the back, then a thick trocar was introduced blindly from the renal surface into the pelvis, because there was no means of guidance. Heavy bleeding often occurred. Since this was only a palliative treatment, there was a big imbalance between the risks of the invasion and the possible gains.

A week previously, we had taken delivery of a new machine direct from the manufacturer. It was the world’s first mechanical sector scanner with a special attachment, which we had designed originally for real-time puncture guidance. After intense discussion among the staff of the risks involved, we made up our minds to introduce the machine in this case. None of us had yet used it, and only a few foreign reports on the procedure were available at the time, which was named later as percutaneous direct nephrostomy.

The patient was moved to the operating theater for general anesthesia. The scanner was positioned on her back, and a clear image of the hydronephrotic renal pelvis appeared on the oscilloscope. All the staff member of our department gathered and watched the operation, praying to God for success. At the first shot, puncture to the pelvis was achieved very easily and a catheter was placed correctly in a few minutes. Everybody was amazed and felt that this was a real innovation.

Only several months later, I found incidentally a young resident carrying out the same interventional operation at the bedside under local anesthesia. He was never nervous but was smiling, joking with the patient. Of course all the procedure was completed in safety. I understood that the technique had already been subsumed into everyday routine work.

The Period of the Central Canal Type Transducer

It is very difficult to determine who made the first application of interventional ultrasound, because ultrasound pictures were commonly used as reference images for puncture, even before the proposal of intervention techniques. Among the pioneers, Berlyne in England is generally credited as the person who made the first trial intervention. He performed renal biopsy under the guidance of an A-mode chart recorded by an industrial flaw detector in 1961, only a few years after the first introduction of ultrasound in medicine.

In my opinion, however, the history of interventional ultrasound should start from the first development of a special apparatus designed purely for the puncture guidance.

A Danish urologist, Hans Herik Holm, and an American radiologist, Barry B. Goldberg, independently published the same idea of a “central canal” type transducer in the same month in different journals in 1972. Both transducers were designed to be attached to a “contact compound” B-mode scanner, which was the standard procedure for sonography at that time, to target the site by a needle inserted through the central canal of it.

Holm’s group pioneered puncture to various organs with their transducer: the liver, pancreas, kidney, uterus, and so on. They used the term “ultrasonically guided puncture” for the procedure. On the other hand, Goldberg focused the object mainly on the aspiration of various fluids from within the body. “Ultrasound-aided needling” was his favorite term. However, a new term, “interventional ultrasound,” which was derived from basic radiology terminology, has gradually become general at the international level since the 1980s, because this describes the technique compactly and sounds harmonious.

Though it is accepted that these two groups opened up the possibilities of ultrasound intervention, their idea of the transducer...
having a central canal was not original. Earlier in 1969, an Austrian gynecologist, Alfred Kratochwil,\(^4\) (Fig. 1.5), had already presented before a congress his trial on puncture to the amniotic cavity with a similar type of transducer developed by him, which was attached to an A-mode (only the intensity of the echo signals is shown on an X–Y graph) machine.

Anyhow, at this stage of the development, the procedure had not yet become very popular, because the imaging technique was inadequate for intervention. In the former “contact compound” scanning, a 2D image was constructed manually with the transducer being slid around the body surface. It took a considerable number of seconds to complete a cross-section picture. Although the target could be indicated on the picture, it vanished when the needle was inserted. No monitoring of the needle pathway was possible. Of course, A-mode gave far less information than B-mode.

**The Period of Real-Time Intervention**

The emergence of real-time scanners in the late 1970s eliminated the weak point mentioned. Only after this innovation did interventional ultrasound become accepted as an established technique for puncture guidance.

The first transducer for real-time intervention, though a kind of working model of electronic scan, was reported by a Danish group in 1977\(^5\) (Fig. 1.6). Saitoh and Watanabe in Kyoto developed a commercially available puncture attachment for a newly developed compact mechanical real-time scanner (Fig. 1.7) in 1978\(^6\) and started to seek out various indications of the puncture system in urology. The story described in the prologue happened in those days. Goldberg et al. also reported their new machine in 1980.\(^7\) Since then many reports have followed from all over the world.

After the introduction of real-time intervention, various kinds of novel diagnostic and therapeutic means, which were never possible in the early days, have been realized. Among these innovations, the most important contributions to medicine, from the viewpoint of frequency of performance, must be selective renal biopsy and percutaneous lithotomy.

In nephrology, renal biopsy is an essential step in the differentiation of diseases. Open biopsy or blind percutaneous biopsy, which was generally performed in the early days, was invasive and risky. Unexpected bleeding occasionally caused a

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**Fig. 1.1.** A portrait of Hans Henrik Holm at the First International Workshop on Diagnostic Ultrasound in Urology and Nephrology, Kyoto, 1979. Hans Henrik has retired but is still active in good health

**Fig. 1.2.** A portrait of Barry B. Goldberg at the same occasion. Barry is hard at work as an academic researcher
fatality. Selective renal biopsy under ultrasonic real-time guidance brought a dramatic improvement of the technique, both in terms of safety and accuracy. Today’s professionals easily take a biopsy sample selectively from a target less than 1 cm in diameter in any portion in the kidney under local anesthetic.
Percutaneous lithotomy was also revolutionary for the treatment of urinary calculi. This generated the vogue word, “Perc,” among urologists in the late 1980s. Saitoh first succeeded in percutaneous nephroureterolithotomy using a special ultrasonically guided pyeloscope in a single stage (several previous reports were available on lithotomy through an already-established nephrostomy channel by surgery) in 1981.

**Intervention by Transrectal Ultrasound**

Transrectal ultrasound is a special technique developed for urology in 1967. In the early period of the method, horizontal sections were obtained by rotation of a single transducer inside the transrectal probe with an electric motor set outside the probe, while sagittal sections were made by manual pulling-down of the transducer. Even in this period, prostate puncture guidance was feasible, but the introduction of a real-time transrectal transducer encouraged the rapid distribution of the method at the worldwide level.

In this case again, the Danish group and the Japanese group were competing with each other. Holm and Gammelgaard published a needle guidance system for puncture to the prostate and the seminal vesicles, monitored by ordinary transrectal ultrasound in 1981. On the other hand, Saitoh and Watanabe had reported a puncture system using a newly developed transrectal electronic linear scanner with a needle guidance attachment in 1980. In this system, a longitudinal section of the prostate was delineated to monitor the advance of the needle directly in real time. Some authors followed this system, employing Japanese probes, then ultrasound intervention came to be recognized as an indispensable procedure for prostatic biopsy. In recent days, the system has been modified to enable switching between two sections, horizontal and longitudinal, by using two different transducers fixed rectangular at the tip of the transrectal probe.

As is well known, the diagnosis of prostatic cancer is made by prostatic biopsy guided by interventional transrectal ultrasound.

**Fig. 1.7.** A mechanical sector scanner with a puncture attachment by Saitoh et al.

**Fig. 1.8.** A portrait of Masahito Saitoh, during his first successful surgery for single-stage percutaneous nephroureterolithotomy in 1981

Percutaneous lithotomy was also revolutionary for the treatment of urinary calculi. This generated the vogue word, “Perc,” among urologists in the late 1980s. Saitoh (Fig. 1.8) first succeeded in percutaneous nephroureterolithotomy using a special ultrasonically guided pyeloscope in a single stage (several previous reports were available on lithotomy through an already-established nephrostomy channel by surgery) in 1981.

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As is well known, the diagnosis of prostatic cancer is made by prostatic biopsy guided by interventional transrectal ultrasound.

**Fig. 1.9.** Transrectal real-time linear scanner with a puncture attachment by Saitoh et al.
alone today. Lee17 and Cooner18 promoted this routine in the late 1980s in the United States. Stamey and Hodge19 established the concept of multicore biopsy, which is accepted as the gold standard worldwide.

Brachytherapy (radioisotopes' implantation) for prostatic cancer has become very common. Nowadays more than 60,000 patients a year undergo the procedure in the United States. Although originally conducted by retropubic open surgery,20 the introduction of transperineal seeds insertion under interventional transrectal ultrasound by Holm21 in 1981 greatly improved the technique. Presently available equipment for this therapy mostly benefits from his improvement.

References for Interventional Ultrasound

In the final part of this chapter, the titles of special books for interventional ultrasound published during the period described (Fig. 1.10) will be listed.

The first book for this purpose was *Ultrasonically Guided Puncture* written in Japanese language in 1979.22 This was planned to publish the results of a special symposium with the same title, organized by the Japan Society of Ultrasonics in Medicine in December, 1978, in Kyoto. With the expanding demand in the field, another book written in English, *Interventional Real-Time Ultrasound* was published in 1985.23

The Danish group released two books for the same purpose in 198024 and in 1985.25 They were based upon the two meetings of the International Conference on Ultrasonically Guided Puncture, held in Copenhagen in 1978 and 1983, sponsored by the Danish Society of Diagnostic Ultrasound. The first book dealt mainly with the central canal type transducer, while the second focused on real-time intervention.

Another essential book26 and important articles on the history of interventional ultrasound27–31 are also listed here.

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Fig. 1.10. Special books on interventional ultrasound
23. Watanabe H, Makuuchi M (edit), Interventional real-time ultrasound (189 pages), The first book on realtime interventional ultrasound. Descriptions on what happens in the kidney tissue by puncture analyzed by biophysics are very important, Igaku-Shoin, Tokyo (1985).
24. Holm HH, Kristensen JK (edit), Ultrasonically guided puncture technique (128 pages), Munksgaard, Copenhagen (1980).
Chapter 2
Laparoscopic Ultrasonography

Surena F. Matin

Introduction

For all the advantages of laparoscopic or robotic-assisted laparoscopic surgery, the absence of tactile sensation and haptic feedback (or the ability to mentally see what is touched) remains a major disadvantage for the novice as well as the experienced surgeon. With experience, laparoscopists can actually gain some sensation through the instruments, and both laparoscopic and robotic surgeons can visually sense the characteristics of tissue being manipulated. But, this is by no means a substitute for actual manual palpation and haptic sensation. Technological advances that allow for force-feedback are still in development and not yet a commercial or clinical reality. In this environment, laparoscopic ultrasonography (LUS) plays a critical and dominant role. Just as importantly, LUS uniquely provides internal visualization of the organ. Ultrasonography is used routinely even during some open operations when it is felt to be superior to manual palpation, such as for staging of upper-gastrointestinal malignancies, evaluation of hepatic malignancy, or in cases of complex partial nephrectomy. 1–4

LUS has many advantages over transcutaneous ultrasonography. For one, transcutaneous ultrasonography is not effective through the pneumoperitoneum, and even for retroperitoneal organs, gas tracking in the soft tissues can significantly degrade the picture. Second, direct contact with the organ in question, such as the liver or kidney, allows the use of higher frequencies, which significantly improve image resolution. With higher frequencies, depth of penetration is lost, but this is usually not a concern due to the proximity of the organ. 5 Third, new probes that are actively steerable in two dimensions can be guided around the organ to provide visualization through a variety of angles and windows.

LUS does have some disadvantages. The direct contact does not allow for visualization of surface abnormalities because they are just within the focal zone. In these cases, a spacer is needed between the transducer head and the organ surface in order to bring the surface lesion within the focal zone. While guiding the laparoscopic ultrasound probe and interpreting the images, it may be difficult for the surgeon to also manipulate the machine settings because of the sterile field, and most operating-room circulators are not trained as ultrasound technicians. This adds a layer of complexity and potential frustration for the surgeon, but the concern is nullified when a radiologist is present with a dedicated ultrasonography technician. On the other hand, laparoscopic skills are required for steering the laparoscopic ultrasound probe, a skill that most radiologists do not have and may not be able to perform efficiently during surgery. It is therefore incumbent on our specialty to provide detailed instruction to urologists for performing and interpreting intraoperative LUS. And finally, it is difficult to visually guide the probe while simultaneously interpreting the ultrasound image; thus, having a picture-in-picture capability aids the process markedly (Fig. 2.1).

The first intraoperative LUS was performed in 1958, and one of the first practical uses of intraoperative ultrasonography was for localization of renal stones. 6–9 Dedicated laparoscopic probes became available in 1983.10 Intraoperative ultrasonography in these early days was limited by poor imaging and limited image interpretation. These limitations dissipated with the advent of high-frequency real-time B-mode ultrasonography. 6 Only with the recent acceptance in the use of laparoscopy and the increasingly early detection of some malignancies, such as renal cell carcinoma, has LUS gained in popularity within the urology community. 5,11

Clearly, the most important role of LUS at present is for renal surgery, where it is incorporated more and more in different types of renal procedures as will be described later. Its use in miscellaneous other procedures, such as adrenalectomy, and other urology procedures is also described.

Laparoscopic Ultrasonography Technology

Medical ultrasound frequencies range from 1 to 30 MHz.12 The transducer transmits ultrasound waves and receives the reflected echo. Image resolution and tissue penetration are determined by frequency – the lower the frequency, the lower the resolution but the greater the tissue penetration. Percutaneous
ultrasonography typically uses 5-MHz frequencies, whereas frequencies of 7.5–10 MHz are typically employed for LUS. A probe with a frequency of 7.5 MHz has the best image obtained between 1 and 4 cm. At this frequency, the ultrasound probe can detect tumors as small as 3 mm, cysts as small as 2 mm, and stones as small as 1 mm.\textsuperscript{12,13}

Generally, different types of transducers are utilized for LUS (Fig. 2.2). The linear-array transducer has a series of multiple transducers placed longitudinally. This transducer works best for organs with a large flat surface, such as the liver. Another type of transducer has a convex array, which increases the field of view and works best for organs with a curved surface, such as the kidney, where only a small amount of surface contact is possible.\textsuperscript{14} Recent advances to both types of transducer probes include an actively steerable, articulating tip, which enhances the flexibility of the entire unit and permits direct-contact scanning over irregularly shaped solid organs. This author finds the convex array to be most ideal for use during renal laparoscopic surgery, because the surface of the kidney is curved and a linear probe does not always provide sufficient surface contact for adequate imaging. Water or saline may be instilled via an irrigation device to eliminate any air pockets to optimize imaging.

Contrast-enhanced ultrasonography uses a contrast agent consisting of gas-filled microbubbles to provide vascular contrast enhancement. Its use during laparoscopic catheter ablation was investigated in an animal model, and its utility during transcutaneous ultrasonography for monitoring recurrence has also been evaluated.\textsuperscript{15,16} This topic is covered in more detail elsewhere in this textbook.

### The Radiologist, the Urologist, and Laparoscopic Ultrasonography

In some centers in the United States, a radiologist is present to perform LUS and provide image interpretation.\textsuperscript{11,17,19} This radiologist is familiar with the operating room and with sterile procedures and is experienced with LUS technology, laparoscopic manipulation of instruments, and of course, sonographic interpretation. A technician typically accompanies the radiologist in manipulating the machine settings, troubleshooting, and making measurements. It is a reality, however, that many academic centers and most community hospitals either do not have the resources to provide for a dedicated radiologist to cover surgical cases or have no one on the staff that is able to or interested in performing LUS. As well, due to the logistics of scheduling, different radiologists with different skills may be available on different days, which results in inconsistent service. Thus, the radiologist’s role is increasingly supplanted by the operating surgeon. At our center, routine cases are usually performed solely by surgeons, in both urologic and surgical oncology. While ultrasonography technique and image interpretation require considerable experience, this training is increasingly being incorporated into postgraduate and residency programs. Diagnostic ultrasonography is currently a part of surgical training in many European and Japanese medical centers where, like a stethoscope, it is considered an extension of the physician’s armamentarium.\textsuperscript{17,19} In fact, a survey by the European Society of Urological Technology found that nearly 80% of respondents performed ultrasonography themselves or they performed them in conjunction with a radiologist.\textsuperscript{19} It is important to note that if the urologist performs the intraoperative ultrasonography, the operative note must be adequately documented to facilitate proper coding and billing (see Fact Sheet). Currently, the code is the same whether treatment approach is a laparoscopic or an open procedure.

### Fact Sheet

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<td>Ultrasound guidance, intraoperative</td>
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<td>• Tumor appearance (hyper echoic, hypoechoic, or isoechoic to normal renal parenchyma; heterogeneous or homogeneous; circular or irregular; sharp or indistinct borders, etc.)</td>
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\textsuperscript{Note that in 2007 the code was changed from 76,986, with no change in the amount of charge. Source: CPT\textsuperscript® 2007 Professional Edition, published by the American Medical Association, Chicago, IL.}
Lus During Renal Procedures

Probe Ablation: Cryotherapy

Uchida and associates first reported the use of percutaneous cryotherapy for renal cell cancer and angiomyolipoma in 1995, and their report was followed soon after by descriptions of open and laparoscopic approaches. In all reports, ultrasonographic guidance and monitoring has been an essential adjunct for observing the evolving cryolesion. Ultrasonography and cryoablation are well-matched technologies. The edge of the evolving ice ball is superbly visualized during...
cryoablation, allowing real-time evaluation of the entire zone of treatment. This advantage forms the central pillar supporting the use of cryoablation for the treatment of small renal masses, as no other form of ablative therapy can be monitored well during treatment.

It is surprising to some that, despite the minimally invasive nature of the procedure, the degree of intracorporeal dissection required for laparoscopic cryoablation is actually quite extensive, as exposure of the entire renal surface as well as the side opposite the lesion is required. An articulating LUS probe with color Doppler capability is inserted through a 12-mm midaxillary port. Examination of the entire kidney is performed to evaluate tumor size, location of margins, and vascularity of the tumor and its proximity to the collecting system, as well as to rule out previously unidentified tumors. Needle biopsy is taken immediately prior to ablation. LUS as well as visually (inset). The iceball itself is anechoic but its edges of the iceball, which usually requires significant previous dissection of the kidney to allow steering of the probe through multiple windows around the kidney. Cryoablation is carried out beyond the tumor edge visually and ultrasonographically, by at least 5 mm in order to ensure an adequate treatment margin. The iceball edge corresponds to about 0-degrees Celsius, while 5 mm inside the edge the temperature is at about -20-degrees, which is the minimum temperature required for adequate cell kill. Sonographic monitoring of the second freeze is suboptimal, as the ablated area is anechoic. However, continued monitoring ensures that the secondary ice ball does not advance beyond the initial boundary.

Probe Ablation: Radiofrequency Ablation

Laparoscopic radiofrequency ablation (RFA) is generally carried out for anterior or lower-pole tumors that are inaccessible percutaneously or that are adjacent to visceral organs or the ureter (in case of a lower pole tumor) whereby a percutaneous approach may not be feasible. Alternatively, a laparoscopic approach may be favored by some, particularly if there is a limitation in accessing a skilled interventionalist.

Transperitoneal access is obtained and the colon is reflected. In the case of a lower-pole tumor, the ureter is mobilized away from the tumor and the lower pole of the kidney mobilized laterally. Similar to cryoablation, Gerota’s fascia is opened surrounding the tumor and the surface of the kidney is exposed. Identification and characterization of the tumor is performed using LUS. Tumor size, enhancement characteristics, proximity to vessels, and the collecting system are all noted. Ultrasoundography of the entire kidney is performed to rule out any other tumors that may not have been seen on preoperative imaging. We also mark the treatment edge, located at least 5–10 mm beyond the tumor edge, with cautery. During RFA there is significant dessication and retraction of the tumor and surrounding parenchyma, making the treatment margins difficult to discern after treatment has begun. Having an anatomic landmark thus aids with establishing proper boundaries. A needle biopsy is taken immediately prior to ablation. LUS is used to guide the initial insertion of the RFA probe to the deepest margin of treatment, because this is the most critical and most difficult area in which to obtain a margin. Once RFA has been initiated, the ultrasound picture begins to degrade significantly due to interference from the radiofrequencies and also from microbubbles that form around the electrode (Fig. 2.4). Several modern ultrasound machines have filters for minimizing this interference, but it is this author’s experience that these filters do not work as well with renal RFA as they do with liver RFA, possibly because of the closer proximity of the electrode to the LUS probe with renal RFA. Thus, after RFA is initiated, there is little use for LUS during the treatment. This emphasizes the importance of accurate initial guidance of the probe into the deepest margin of treatment by using LUS. After the initial ablation, multiple sequential, overlapping, more superficial ablations are performed using a standard algorithm until complete ablation of the tumor and margin is achieved.

Laparoscopic Partial Nephrectomy

The technique described by the group at the Cleveland Clinic26,27 has become the de facto standard for laparoscopic partial nephrectomy (LPN), with few modifications made at other centers. The routine use of LUS, cystoscopic placement
of a ureteral catheter, suture repair of the collecting system, and renorrhaphy are used by most practitioners, but with growing experience, ureteral catheters can be omitted when tumors are completely exophytic and when resection is not expected to violate the collecting system. Hilar clamping is routinely performed to obtain vascular control using bulldog clamping of the renal artery alone or in combination with the renal vein during a retroperitoneal approach or using a laparoscopic Satinsky clamp during a transperitoneal approach. This allows resection in a bloodless field with optimal visualization of the margins of resection. Similar to any other form of nephron-sparing surgery for cancer, LUS allows evaluation of the entire kidney for lesions that may have been missed on preoperative imaging or lesions that may have progressed since the last preoperative imaging. As resection of an additional margin during LPN is difficult and to be avoided if at all possible, determination of the resection margins using LUS is critical (Fig. 2.5). This is particularly true for deeper lesions, those with a significant intrarenal component, or those that are irregular in shape (Figs. 2.6 and 2.7). LUS has thus become a standard and expected adjunct to LPN for all tumors except maybe those that are obviously only cortical.

Renal Cyst Decortication

Laparoscopic decortication of symptomatic renal cysts is preferred over percutaneous aspiration due to the risk of recurrence with the latter, and certainly at this time is preferred to open surgery because it is a minimally invasive procedure. Elashry and colleagues reported two patients who underwent five LUS-guided cyst marsupialization procedures. A 10-MHz laparoscopic ultrasonic unit with an articulating tip was used to identify perihilar and hidden subcapsular cysts. Color Doppler imaging allowed discrimination of peripelvic cyst anatomy and surrounding vasculature, permitting safe
decorticication of cysts adjacent to hilar vessels. McDougall has nicely described the laparoscopic approach to decortication of simple cysts and polycystic kidneys. 31

Laparoscopic Renal-Stone Surgery
In 1977, Cook and Lytton 29 employed ultrasonography during an open nephrolithotomy using a 10-MHz probe that detected stones 2–3 mm in diameter, as judged by cadaveric studies. In their reports, ultrasonography was able to locate calculi in six patients who were otherwise difficult to identify. 7 The advantages observed during open renal-stone surgery prompted the use of LUS during laparoscopic nephrolithotomy and other laparoscopic renal-stone surgery. Van Cangh et al. 32 initially reported the technique of laparoscopic nephrolithotomy in a patient with a 2-cm renal calculus who had previously failed shock wave lithotripsy and was not a candidate for percutaneous therapy. LUS was felt to be critically important for accurate localization of the calculus. Additionally, the use of duplex ultrasonography assisted in the selection of a relatively thin, avascular site for the nephrotomy.

LUS appears to be eminently useful during laparoscopic calyceal diverticulectomy. Ruckle and Segura 33 reported laparoscopic obliteration of a stone-bearing calyceal diverticulum, but adjunctive ultrasonography was not employed because of the thin overlying cortex, which allowed ready visual identification of the diverticulum. The use of LUS in the laparoscopic approach to calyceal diverticula has since shown great utility, as these lesions may not be readily identifiable by visual inspection of the cortex, even after complete exposure of the kidney. 34 Miller et al. 35 have also described their technique in five patients, all of whom had complete stone clearance and obliteration of the diverticulum.

LUS may also aid in locating the calculus within the renal pelvis and may facilitate laparoscopic extraction. 36 Because the superior resolution of higher-frequency LUS probes allows detection of stones as small as 1–2 mm, the use of LUS may also reduce the risk of leaving small fragments during other types of laparoscopic stone surgery. LUS during laparoscopic renal-stone surgery is a useful and dependable adjunct that can facilitate real-time localization of a calculus, can guide surgical planning, and identify residual calculi.

Lymphocele Marsupialization
The definitive approach to symptomatic sterile pelvic lymphoceles involves drainage within the peritoneal cavity. 37 Open or laparoscopic marsupialization of the lymphocele into the peritoneal cavity is achieved by creation of a window in the common wall between the two cavities. Percutaneous treatment by simple aspiration is associated with significant