Curr Urol Rep (2012) 13:460–466
DOI 10.1007/s11934-012-0280-y

Office Ultrasound for the Urologist

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Published online: 30 September 2012

Abstract Imaging of the genitourinary tract is essential in the workup of the majority of the conditions seen daily by urologists. The use of ultrasound in the office provides a safe, low cost, and efficient way for the clinician to evaluate the patient in real time. Ultrasound can allow for bedside diagnosis in many conditions and assist in treatment planning. This chapter covers the major applications of office ultrasound for the urologist as well as discusses future applications of ultrasound for the office setting.

Keywords Ultrasound · Doppler · Renal · Penile · Scrotal · Bladder · Prostate · Accreditation · AIUM

Introduction

Ultrasound is the portion of the acoustic spectrum characterized by sonic waves that emanate at frequencies greater than that of the upper limit of sound. Austrian neurologist Karl Dussik is credited with being the first to use ultrasound as a diagnostic tool in 1940 to map the human brain [1]. Since that time, ultrasound technology has progressed to become an integral part of many fields of medicine, especially, urology. Ultrasound is a cost-effective, accurate, and nearly ubiquitous easy to use diagnostic tool that produces meaningful results instantly. As a standard in the urologist's office armamentarium, it can be applied to the work-up of pathology of the genitalia, pelvic floor, bladder, prostate, and kidneys. Specific uses within each organ system will be discussed.

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Basic Ultrasound Principles

Ultrasonography may be performed in the office using either a stationary or portable machine. Ultrasound technology is based on the interpretation of sound waves as they are reflected off an interface between body tissues. Most of the energy from the ultrasound probe is attenuated by absorption, reflection, or scattering from the area of interest. The non-attenuated energy is reflected back to the probe to form the image. The degree of attenuation is proportional to the frequency of probe used, with a higher frequency probe yielding a greater resolution image but less penetration into the tissue. The choice of ultrasound probe should be ideally selected for the organ of interest and patient factors that form the best image to evaluate the patient [2].

Documentation is key to any ultrasound images obtained in the office. The written report and archived images are a reflection of the quality of the examination. The static images obtained during the evolving ultrasound exam should represent the sonographer's impression of the findings. If electronic storage space is available and the equipment allows, video clips, which demonstrate important findings, can and should be obtained. Each image should include the date, the time, patient identification, the indication for performing the exam and the transducer used and its frequency. The orientation and measurements should be clearly labeled along with the pertinent anatomy and any abnormalities. There is no minimum number of images that are required for proper documentation.

Ultrasound has an excellent safety record. The American Institute of Ultrasound in Medicine (AIUM) most recent statement on Prudent Use and Clinical Safety states that

"No independently confirmed adverse effects caused by exposure from present diagnostic ultrasound instruments have been reported in human patients in the absence of contrast agents." However, when ultrasound propagates through tissue there is always the potential for tissue damage. The risks and benefits of each ultrasound exam should be discussed with the patient and considered by the physician performing the exam. The safety of ultrasound devices is controlled by FDA regulatory output limit. At least two potential mechanisms of tissue damage are of concern: the thermal heating of soft tissue and non-thermal mechanical phenomena such as cavitation, damage due to exposure of soft tissue that contains gas bodies (eg. lung and intestine) [3]. For this reason, when performing an ultrasound exam, the ALARA (As Low As Reasonably Achievable) principle should be advocated. The practitioner performing the ultrasound should focus on adjusting the controls that affect the acoustic output and attempt to minimize transducer dwell times [4••].

In addition, routine maintenance of equipment and prevention of infection by disinfection of the transducers before and after each use is also extremely important. Each office should develop a standard operating procedure manual that states the policy and documents compliance with it. Manufacturers' guidelines must be followed. Any patient complications or equipment malfunction needs to be documented with follow up recorded.

Accreditation for a urology practice to perform ultrasound is now available through a pathway created by the American Institute of Ultrasound in Medicine (AIUM) and the American Urological Association (AUA). The AIUM is a multidisciplinary association dedicated to the safe practice and future development in ultrasonagraphy. It should be emphasized that this practice accreditation is voluntary and is not required by the AUA for a urologist to perform office ultrasound. However, accreditation might allow the urologist to receive reimbursement for ultrasound examinations performed in the office by some insurance carriers. The AUA provides Hands-On training courses to teach proficiency in ultrasound under the mentorship of an experienced sonographer. Additionally, residency training programs are now required by the residency review committee to track the number of ultrasound exams performed through their training.

Office Ultrasound

The performance of ultrasound in the office is a critical part of the armamentarium of the practicing urologist. Ultrasound allows for evaluation of nearly all structures in the genitourinary tract at the bedside. Ultrasonography may be used as a continuation of the physical exam and allow for excellent imaging of the patient from the time of initial visit with the urologist.

The ultrasound device purchased by the practice is dependent on the planned usage of the device. The majority of urology practices have a transrectal probe that is commonly used for imaging of the prostate and prostatic biopsy. Additional transducers are needed for evaluation of the other urologic organs. The choice of frequency used is dependent on a balance of depth of penetration to detail of the image. It is best to use a multiple frequency transducers that allow the transducer to be set at one of several distinct frequencies. The purchase of additional transducers is often helpful: a linear array probe, best for assessment of the testis and penis, as well as a curved array probe that can be used for kidney, bladder, and for patients with thickened scrotal wall. The following sections will describe the major indications for office urology ultrasound by organ system as well as specific conditions in which office ultrasound might influence treatment (Table 1).

Scrotal US

There are many specific indications for scrotal ultrasound for the office-based urologist. Scrotal ultrasound is performed when the physical examination is inconclusive or difficult to complete due to patient discomfort or inability of the examiner to precisely identify the scrotal structures on palpation. In these instances the scrotal ultrasound examination is an integral part of the physical examination of the

Table 1 Examples of where office ultrasound might influence clinical diagnosis and treatment

Scrotal	Trauma: Evaluation of integrity of tunica albuginea
	Pain: Evaluation of epididymal and testicular blood flow
	Mass: Identification of cyst, tumors and paratesticular lesions
Penile	Erectile dysfunction: arteriogenic, veno-occlusive, neuro genic origin
	Peyronie's disease: calcification, thickness, erectile function
	Priapism: differentiate high and low flow
	Trauma: assess corporal integrity, vascular injury
	Urethral disease: spongiofibrosis, stricture length
Renal	Flank pain: stone disease, hydronephrosis, cystic disease
	Hematuria: stone disease, mass
	Renal failure: chronicity, hydronephrosis
Bladder	LUTS: Assess for median lobe, post void residual and chronicity (wall thickness)
	Hematuria: stones and lesions
Prostate	Infertility: midline cysts, seminal vesicle or ejaculatory duct dilation
	LUTS: prostatic enlargement, median lobe
	Malignancy: biopsy to detect prostate cancer

male genitalia. Additionally, scrotal wall lesions, inguinal hernias, infectious, malignant and inflammatory conditions can be assessed by office scrotal ultrasound. Color and spectral Doppler are essential elements of a scrotal ultrasound because they provide documentation of normal testicular blood flow and paratesticular findings.

Ultrasound is especially helpful when physician or self-exam reveals a testicular or paratesticular masses. Testicular tumors are well visualized with ultrasonography. Seminoma often has the sonographic appearance of a homogeneous, well-defined hypoechoic lesion. Cystic areas are found only in 10 % of cases [5]. Non-seminomatous germ cell tumors have ultrasound findings that reflect the diversity of the components of the tumor. They typically appear irregular with a heterogeneous parenchyma pattern, representing calcification, hemorrhage, fibrosis and cystic lesions [6, 7]. These findings are used to differentiate from the anechoic appearance of testicular cysts and hydroceles.

Scrotal ultrasound is vital in the assessment of a patient with scrotal trauma. Physical examination may be difficult in patients with scrotal trauma due to tenderness and swelling. Scrotal ultrasound is the standard imaging study to evaluate testicular and epididymal integrity and assess the vascular status of the testis [8]. A discrete line or hypoechoic stripe in the testicular parenchyma is evidence of testicular rupture with disruption of the tunica albuginea [9]. The sensitivity of ultrasound for detecting testicular rupture related to blunt trauma is considered to be 100 % and specificity is 65–93.5 % [10, 11]. The management of testicular rupture is early surgical intervention with the goal of preventing testicular loss. This recommendation is also applied in boys with a hematocele found on ultrasound as up to 80 % of significant hematoceles are due to testicular rupture [11, 12].

Ultrasound is often used to assess boys and adolescents with acute scrotal pain when the urologist is concerned for testicular torsion. Despite the findings that color Doppler sonography has a sensitivity and specificity above 95 %, it is our feeling that torsion remains a clinical diagnosis proven only at surgery. Ultrasound should only be used to document findings. On gray scale ultrasound, the affected testis usually appears hypoechoic and hypertrophic with Doppler color flow study demonstrating decreased or no flow in the affected testis. Again, ultrasound does not diagnose or "rule out" torsion.

Ultrasonography is also an important component of the workup of male factor infertility. A varicocele is present in about 15 % of normally fertile men, in 30 % to 40 % of men with primary subfertility, and in as many as 80 % of men with secondary subfertility [13, 14] Varicocele repair improves the semen parameters in approximately 70 % of the patients [15–17] (Fig. 1). Scrotal ultrasound documents testicular and varicocele size both before and after treatment. Ultrasound is useful in patients with congenital bilateral absence of the vas deferens (CBAVD) to assess other developmental defects and associated conditions such as congenital renal agenesis [18, 19]. Recent literature supports the use of spectral Doppler ultrasound in providing information about intratesticular blood flow and function [17, 20•, 21, 22]. Mean resistive index (RI) greater than 0.6 is associated with impaired spermatogenesis [20•].

Penile US

Evaluation of a patient with erectile dysfunction (ED) is the most common utilization of penile ultrasound for the clinical urologist. Penile ultrasound may also be used for evaluation of penile curvature, priapism, tumors, trauma, foreign bodies, or urethral pathology. Color and spectral Doppler are essential elements of penile ultrasonography. Pharmcostimualtion with intracavernosal injection therapy should then be given after informed consent with the patients regarding the risks and benefits if the agent used [4••]. The patient is counseled about the known risk for developing a priapism and appropriate follow-up if this were to arise [23]. At serial time points following the injection of vasoactive medication, cavernosal artery dimensions and flow velocities should be recorded.

Ultrasound performed after pharmacotherapy in patients with erectile dysfunction assesses the quality of arterial blood flow and sufficiency of veno-occlusive mechanisms. Arteriogenic ED is evaluated with measurement of the average peak systolic velocity (PSV). A PSV of greater than 35 cm/s indicates normal arterial supply and a PSV less than

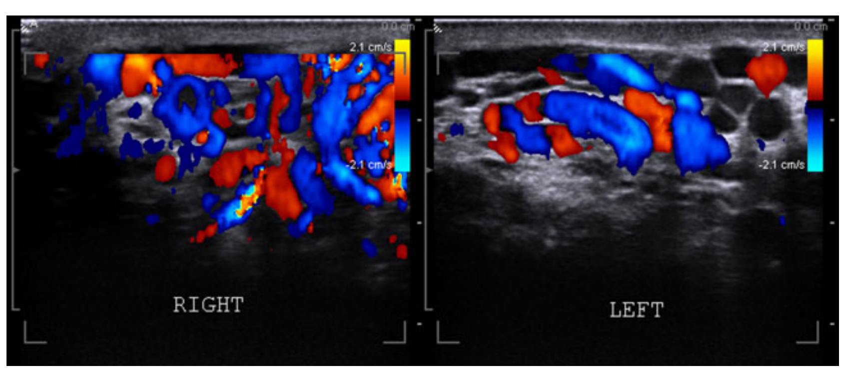

Fig. 1 Scrotal Color Doppler Ultrasound in a 28 year old man presenting with impaired fertility demonstrating bilateral varicoceles

25 cm/s indicates severe areteriogenic disease [24–29] (Fig. 2). Veno-occlusive insufficiency, also referred to as venous leak, is diagnosed in cases of ED that have an appropriate arterial function measured by PSV, and an End Diastolic Velocity (EDV) greater than 5 cm/s throughout the study, especially at the most turgid level of erection [30, 31]. Venous leak has also been highly associated with an RI of less than 0.75 measured 20 minutes following maximal pharmacostimulation [32]. In the absence of a venous leak, a fully erect penis should have an EDV nearing zero and the RI should approach or exceed 1.0. In cases where a RI of 1.0 or greater is achieved, we recommend immediate treatment or prolonged observation to achieve detumescence because of the high specificity of absent diastolic flow for priapism [33].

Arteriogenic ED has been found to correlate directly with other systemic cardiovascular diseases, both coronary artery disease (CAD) and peripheral vascular disease [34, 35]. Vessel compliance is compromised in arteriogenic ED as in CAD. Diagnosis of patients with vasculogenic ED may provide a lead-time on otherwise silent and undiagnosed cardiovascular disease [34, 36, 37•]. Diagnosis of arteriogenic ED can be lifesaving to patients, as it can identify patients at high risk of cardiovascular disease, and referral to a cardiologist is recommended.

Penile ultrasonography is also important in patients with penile curvature or Peyronie's disease. Fibrotic plaques can be visualized as hyperechoic or hypoechoic areas of thickening of the tunica albuginea and may have elements of calcification [38, 39]. Many men with Peyronie's disease have coexistent ED and assessment with ultrasound provides guidance for the most appropriate patient-specific treatment course.

Ultrasound can also be helpful in the assessment of a patient with priapism. In cases of high-flow priapism, ultrasound reveals normal or increased blood flow within the cavernosal arteries and irregular, turbulent flow pattern between the artery into the cavernosal body at the site of an arterial-lacunar fistula, which may be found using a transperineal approach. Ultrasound used to aide in the definitive diagnosis and localization of the cause of high-flow priapism can expedite treatment with selective angioembolization [40]. In contrast, a low-flow priapism on PDU would present with absent or very high-resistance flow within the cavernosal artery.

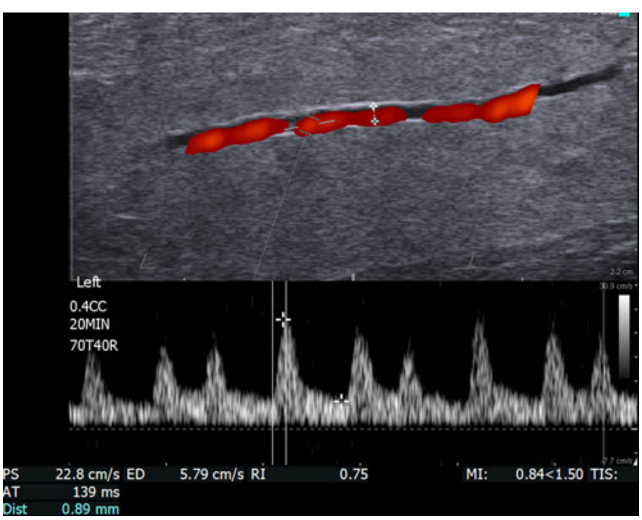

Fig. 2 Transrectal Ultrasound in a 33 year man with low ejaculate volume and pain on ejaculation demonstrating a prostatic utricular cyst

Penile ultrasound may also add to cystoscopic findings in the evaluation of urethral pathology. Ultrasound can provide an economically-sound and non-invasive assessment of urethral stricture, foreign bodies, urethral calculi, divericula, cysts, and abscesses. Although retrograde urethrography is the standard imaging modality for urethral stricture disease, penile ultrasound provides a more accurate assessment of stricture length and diameter in the anterior segment [41–43]. Additionally, penile ultrasound allows for assessment of stricture resulting in periurethral spongiofibrosis whereas a classic urethrogram only assesses the lumen [44].

Renal

Assessment of the kidneys in the office setting may be extremely helpful for the office urologist. Ultrasound is useful for patients with flank pain, hematuria, stone disease, obstruction, trauma, renal insufficiency, or transplant. The findings on renal ultrasound may be vital to the diagnosis of a patient's disease or indicate the need for further diagnostic or interventional procedures.

Ultrasound is a major portion of the workup of medical renal disease. The normal renal cortex should be hypo or isoechoic to the liver. Increase in the echogenicity is indicative of renal disease and has been histologically linked to medical renal diseases including global sclerosis, focal tubular atrophy and hyaline casts [45]. Severe renal disease was seen in 30 % of patients with cortical echogenicity equivalent to the liver and in 66 % with echogenicity greater than the liver [46].

The use of office renal ultrasound is often used to assess for obstruction. Hydronephrosis is often seen when obstruction to the urinary system is present. Bedside ultrasound for hydronephrosis is highly sensitive and specific (92 % and 78 %), performed by emergency room physicians [47]. Routine office ultrasound performed by urologist 4 weeks after ureteroscopy found a 4.8 % rate of silent (assymptomatic) hydronephrosis, in some patients related to residual stone or structure [48•]. Calculating the RI of the renal vessels can demonstrate vasoconstriction related to obstruction that may even precede hydronephrosis. Using the threshold of 0.70, RI predicts obstruction with a sensitivity of 92 % and specificity of 88 % [49].

Renal ultrasound is important in the care of patients with nephrolithiasis. Ultrasound is capable of visualizing renal pelvic or ureteral stones as well as assess for hydrophrosis from a stone obstruction. Stone detection by ultrasound is highly specific, 88 % for renal and 94 % for ureteral stones, however has a sensitivity of 45 % [50]. Ultrasound in addition to a KUB can be an initial screening for stones with decreased radiation exposure [51]. Non-contrast CT has become the standard tool for assessment of patients with renal colic, however renal ultrasound is the recommended initial imaging modality for renal colic in pregnant women and children [52]. Ultrasound is also an excellent imaging study for recurrent stone formers in the office as these patients are at risk of cumulative radiation from multiple CT scans [53]. Office ultrasound can also be used to assess for the success of medical expulsive therapy of a known stone.

Assessment of renal masses can also be done using ultrasound in the office. Simple renal cysts are easily identified as well circumscribed anechoic areas with posterior acoustic enhancement. Complex cysts and parenchymal lesions are normally evaluated with CT or MRI. However, with the use of contrast-enhanced ultrasound, the visualization of septa in complex cystic renal lesions may be superior [54–56]. Additionally, the use of ultrasound is a radiation and contrast free modality to image after renal surgery and for lesions being followed by surveillance.

Bladder

Office ultrasound of the bladder can yield a large amount of information in regards to a patient's voiding and urinary complaints. Many practices have automated bladder scanners that are used to assess a post-void residual. In addition to post-void residual, a complete bladder exam will assess bladder wall thickness, capacity, diverticula, stones, masses, ureteral jets, as well as dilation of the distal ureters [4••]. Responsiveness to alpha-blocker therapy for lower urinary tract symptoms correlates to bladder wall thickness and intravesicle prostate prostrusion [57]. Prostate protrusion may be seen on transrectal or bladder ultrasound and may be used when planning the type of surgical option for treatment of obstruction.

Prostate

Prostate ultrasound is the modality most commonly performed by urologists in the office setting. The prostate ultrasound is normally performed via transrectal approach, but may also be performed from a transperineal or transabdominal approach [4••]. The ultrasound exam allows for measurement of prostate volume which can be used to calculate a PSA density, it can also aid in preoperative preparation for benign/obstructive and malignant etiologies. The seminal vesicles, vasa defertia, perirectal space, and rectal wall are also imaged in this study. Ultrasound is an important component in the evaluation of male factor infertility, especially in the diagnosis of obstructive azoospermia, to assess for dilated ejaculatory ducts, midline cysts, or dilated seminal vesicles [58] (Fig. 3).

The most common use of prostate ultrasound is in the diagnosis of prostate cancer. Prostate cancer most often appears hypoechoic on ultrasound, however ultrasound has a sensitivity and specifity of 40-50 % in detecting cancer [59]. The local staging of prostate cancer may be assessed based on features seen on the transrectal ultrasound. Bulging or irregularity of the prostatic capsule and the length of the hypoechoic region adjacent to the capsule may correlate with extracapsular extension. Seminal vesicle invasion may be seen associated with asymmetry of the seminal vesicles or a hypoechoic area within the seminal vesicle [60]. Visualization of prostate cancer is challenging unless there is gross extension of the tumor. Color and Doppler can increase the detection rate, however localized tumor often do not have sufficient angiogensis to result in significant changes in appearance [59]. Due to these limitations, ultrasound guided prostate biopsy is the standard diagnostic tool for prostate cancer. Biopsy has a false negative rate up to 40 % for the detection of prostate cancer [59]. Additionally, transrectal prostate biopsy has the possible complications of pain, hematuria, rectal bleeding, hematospermia, and infection. Pooled data finds that infection rates are between 0-4 % [61•].

Multiple new technologies are being applied to aid in the detection of prostate cancer and more importantly, clinically relevant disease. Microbubble technology uses gas filled microbubbles with a diameter of 5-10 microns, smaller than a red blood cell, as a contrast agent. These microbubbles stay within the blood stream and microvasculature, therefore ultrasound detection of neovascularity or microvessel density is detected [59]. Investigations have found that microbubble contrast-enhanced biopsies have a higher detection rate of

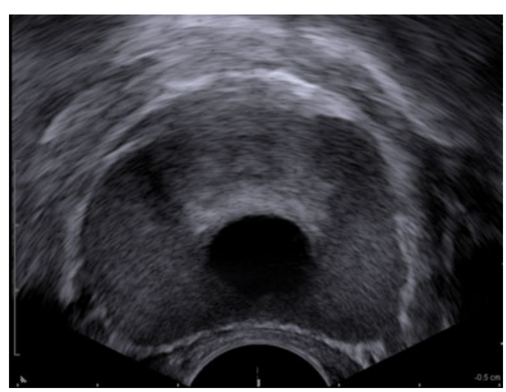

Fig. 3 Penile Duplex Ultrasound in a 66 yo man with arteriogenic erectile dysfunction. Peak systolic velocity is 22.8 cm/sec

prostate cancer, with a decreased number of biopsies performed. Yet when compared to a systematic protocol, the targeted biopsies missed approximately 20 % of cancers [62]. Sonoelastography is another transrectal approach to detect prostate cancer. This technology uses compression and decompression of tissues and the idea that malignant tissues are stiffer than benign tissues. A recent meta analysis found that a sensitivity of 62 % and specificity 79 % for this modality [63]. Prostate HistioScanning is a modality that uses ultrasound technology and incorporates spectral analysis and pattern recognition to detect disease. A comparison of HistioScanning to radical prostatectomy specimen found a 90 % sensitivity and 72 % specificity for the detecting lesions larger than 0.2 mL [64]. Additionally, Prostate MRI has become another promising modality for visualization of possible prostate cancer, yet there are limitations in its implementation due to the cost of MRI and the difficulty in performing invasive procedures in the magnetic environment. New technology is being investigated for the fusion of MRI imagining with real-time ultrasound [65, 66].

Conclusion

The use of ultrasound has utility in many areas of office clinical urology. Office ultrasound allows the practitioner the ability to image nearly all organs of interest in the genital-urinary system. Ultrasound will augment the physical exam and given structural and vascular to assistance in the identification of the patients disease. Familiarity with the equipment and skill to image these structures can be achieved with training through Hands-On courses and accreditation in the use of ultrasound. New technologies and advanced equipment will continue to advance the field of ultrasound and hopefully will assist urologist more and more with the care of their patients.

Disclosure E. Goldenberg has reported no potential conflicts of interest relevant to this article; BR Gilbert has received royalties from Gulf Coast Ultrasound and payment for developing educational presentations for the American Urologic Association.

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- • Of importance
- •• Of major importance

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