JOURNAL OF ENDOUROLOGY
Volume 15, Number 1, February 2001
Mary Ann Liebert, Inc.

# Imaging of the Lower Urinary Tract in Adults

SERGE PETER MARINKOVIC, M.D., and GOPAL H. BADLANI, M.D.




## ABSTRACT

**Imaging of the lower urinary tract is an integral part of everyday urologic practice. Clinical application of less commonly used techniques is discussed to expand their usefulness in an ambulatory setting.**


## INTRODUCTION

ADVANCES IN IMAGING TECHNIQUES have improved the accuracy of assessment of symptoms resulting from lower urinary tract dysfunction. Until recently, imaging of the lower urinary tract was in the domain of the radiologist; however, it is now common for a practicing urologist to perform transrectal ultrasonography for prostate and male infertility assessment, bladder ultrasonography for measurement of postvoiding residual urine volume, and renal ultrasonography to localize calculi. In this paper, we review refinements in some of the available imaging techniques and the modalities on the cutting edge, all with the intent of improving functional assessment of the lower urinary tract. The techniques considered are: (1) videourodynamics for voiding dysfunction; (2) ultrasonography/color Doppler studies for determining urethral strictures; (3) bladder ultrasonography; (4) ultrasonography and color Doppler studies for varicocele evaluation; (5) power Doppler studies for vasculogenic impotence; (6) endourodynamics; (7) use of 5-aminolevulinic acid (ALA) during cystoscopy to detect superficial bladder cancer; and (8) dynamic fast MRI for pelvic prolapse.

## VIDEOURODYNAMICS

Videourodynamics (VUDS)—the use of multichannel urodynamic measurements with concomitant fluoroscopy to define anatomy and function—has been pivotal in enhancing our knowledge of the dynamics of the bladder and outlet. The study can be of benefit in diagnosis and in implementation of a therapy with greater efficacy.[1–3] Measurement of the vesical and abdominal pressures simultaneously under fluoroscopic control obtains significantly more information than does a cystogram or simple cystometry alone. Digital recording of the study allows postprocessing, storage, reproduction, and electronic transfer for remote assessment. Common indications for VUDS in our laboratory include evaluation of male and female incontinence, neuropathic bladder, bladder outlet obstruction, geriatric incontinence, urinary diversion, and undiversion (Table 1).

### *Videourodynamic Equipment*

A multichannel urodynamics machine with C-arm fluoroscopy and a compatible table to reduce the radiation exposure of the urologist are required. The table allows imaging in the supine, sitting, and upright positions. New software allows the urologist to incorporate a patient history, standardized voiding diary, and quality of life measures into the clinical assessment. A Microsoft Office software package permits professional reproduction of the videourodynamic studies with slide-making capabilities. Statistical software is included. Electronic transfer through a modem enables remote assessment. The software calculates pressure–flow points for nomograms (e.g., Abrams and Griffith).

Despite the availability of sophisticated software, the role of the clinician is significant. Correlation of these findings with symptoms can be done only by the clinician.

### *Clinical Use*

**Assessment of Female Incontinence.** In patients with mixed urge and stress urinary incontinence, recurrent stress incontinence after surgical procedures, and those with prolapse, concomitant use of fluoroscopy permits precise assessment of the bladder neck position and coaptation in the absence of detrusor contraction. Measurement of the Valsalva leak point pressure (VLPP) can be done without fluoroscopy; however, the image adds significantly in the planning of a surgical procedure. Assessment of detrusor function, both contractility and

Department of Urology, Northshore-Long Island Jewish Health Systems, New Hyde Park, New York.

TABLE 1. INDICATIONS FOR VIDEOURODYNAMICS

| |
|---|
| Neurologic Disorders |
| Spinal cord injuries |
| Poststroke voiding disorders |
| Parkinson's disease |
| Multiple sclerosis |
| Myelomeningocele |
| Poor bladder compliance |
| Incontinence |
| Intrinsic sphincter deficiency |
| Failed anti-incontinence procedure |
| Urge incontinence |
| Type 2 stress incontinence |
| Bladder Outlet Obstruction |
| Urethral obstruction in females |
| Bladder neck obstruction |
| Poor detrusor contractility |
| Iatrogenic Disorders |
| Post abdominoperineal resection |
| Post radical hysterectomy |
| Post prostatectomy |
| Miscellaneous |
| Pretransplant evaluation |
| Malfunctioning artificial sphincter |
| Pediatric dysfunctional voiding |
| Pelvic prolapse |

Reprinted from reference 2 with permission.

compliance, and its relation to the outlet is improved using simultaneous fluoroscopy and pressure tracings.

**Neuropathic Disorders.** In children with myelodysplasia or cerebral palsy and adults with multiple sclerosis or spinal cord injury, VUDS can gather multiple datapoints in a single setting. In the absence of fluoroscopy, urodynamic studies may be inaccurate, if concomitant reflux is present at low volume or of a high grade, by altering filling compliance, which can affect upper tract function (Fig. 1).[4]

**Outflow Obstruction.** High-pressure voiding with low flow define obstruction, and fluoroscopy allows determination of the site of obstruction (bladder neck, prostate, external sphincter). This information is extremely important in neuropathic patients, patients who are have had radical pelvic surgery, children with posterior urethral valves, and patients with cecoureteroceles.

### *Difficulties with Videourodynamics*

It is of paramount importance to reproduce the patient's symptoms during urodynamic studies or VUDS. If suspected detrusor instability is not demonstrated during the examination, it is recommended to change the fill rate (increasing the fill rate may induce detrusor instability) or the position of the patient (from supine to upright) or to use provocative maneuvers such as coughing or Valsalva (which may also induce delayed detrusor instability or stress incontinence). If incontinence is not demonstrated with the urodynamic catheter in place, removing the catheter and asking the patient to perform a Valsalva maneuver may be all that is needed (e.g., after radical retropubic prostatectomy).

Technical difficulties with VUDS include those related to the urodynamic machine and to the patient. Machine-related difficulties include accuracy and balancing of the transducers and assessing the accuracy of pressure measurements. Sophisticated hardware and software have resulted in computer-related difficulties and loss of data. Technical difficulties with patients are usually with children and the elderly. Children may have to be sedated with chloral hydrate or placed under general anesthesia. Geriatric patients with multiple comorbidities, dementia, and physical disabilities may require assistance with positioning and frequent coaxing during a study. Most of these problems can be circumvented with additional time and patience.

Difficulties with interpretation of a VUDS include its unphysiologic nature, as it is performed in unfamiliar surroundings. If the study does not reproduce the presenting symptoms, it may have to be repeated or done differently (i.e., ambulatory urodynamic studies in patients with symptoms of overactive bladder and absence of demonstrable detrusor instability). Significant pelvic prolapse (cystocele, enterocele, rectocele, and uterine descensus) can also make the interpretation of VUDS less reliable. The true impact of pelvic prolapse may go unrecognized unless the VUDS is performed in various positions. Pelvic prolapse is often an indication for VUDS assessment to determine the impact of the prolapse on detrusor or urethral function, bladder capacity, and flow rate. Reducing the prolapse with a pessary or vaginal packing may unmask stress urinary incontinence.[5]

In conclusion, VUDS has added significantly to our ability to assess patient symptoms. It is highly recommended in complex cases (neuropathic), postoperative incontinence, and refractory cases.

## ULTRASONOGRAPHY AND COLOR DOPPLER STUDIES FOR ASSESSMENT OF URETHRAL STRICTURES

In 1985, McAninch and associates began to use ultrasonography with a 5 MHz transducer for the diagnosis and management of urethral strictures.[6–8] Retrograde urethrography (RUG) has its limitations because it is a two-dimensional study that has limited precision in determining the length of a stricture and the depth of periurethral fibrosis extending into the corpus spongiosum. Inaccuracies in measurements of stricture length may also be related to the RUG being a static imaging modality and to variations in penile stretch, urethral distention by contrast medium, and patient positioning.[8] On the other hand, ultrasonography is a dynamic, three-dimensional study without radiation exposure, making it possible to repeat the study as often as necessary without risk of gonadotoxicity.[9] One can readily obtain cross-sectional and longitudinal images, and the procedure is well tolerated.

Initially, ultrasound gel is applied to the penis, scrotum, perineum, and any other area to be studied. Using a catheter-tipped 60-mL syringe, the external urethral meatus is injected with normal saline while simultaneous ultrasound images of the urethra are obtained with a 7.5 MHz transducer. Imaging starts with the distal penile urethra and is advanced proximally toward the bulbar urethra. After multiple instillations of saline, firm suprapubic pressure is applied so that the proximal aspect of the bulbar urethra or that area proximal to the structure is

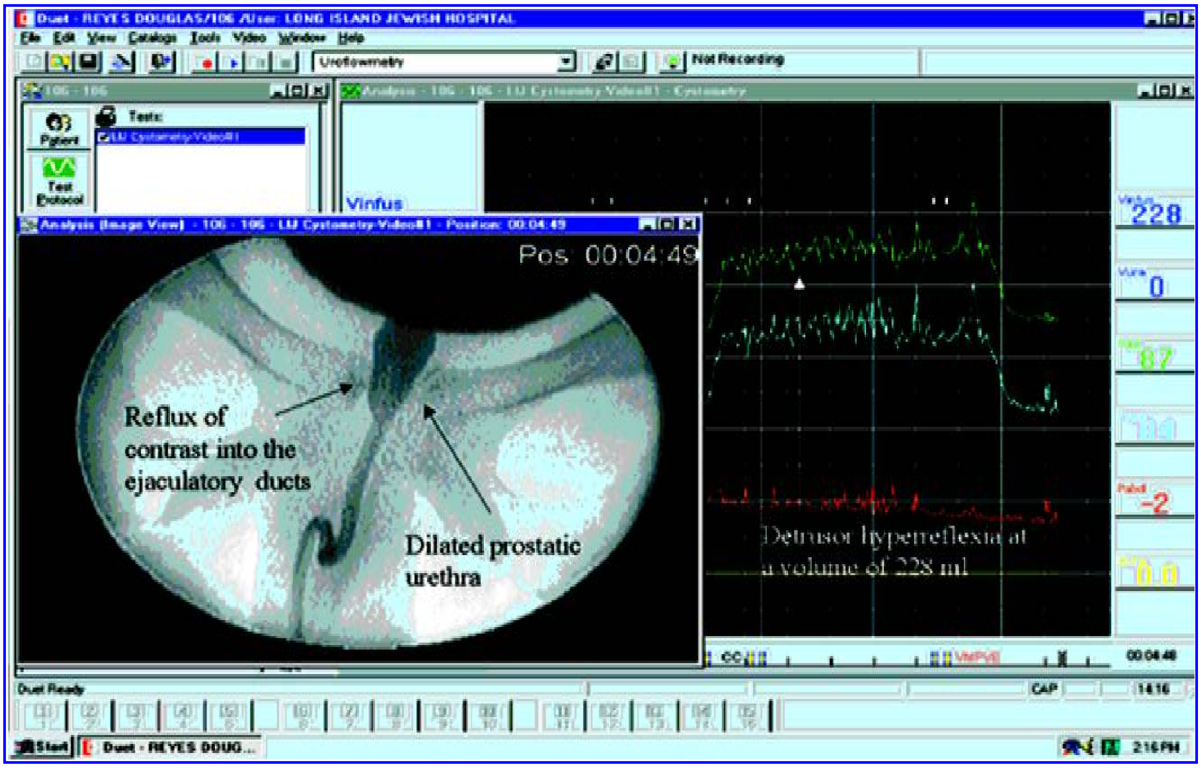


**FIG. 1.** This 17-year-old boy with incomplete $C_5$ lesion demonstrates detrusor–sphincter dyssynergia by reflux of contrast medium into ejaculatory ducts and dilated prostatic urethra, both against closed external sphincter. Detrusor pressure is 87 cm $H_2O$. Cystometrogram demonstrates detrusor hyperreflexia at volume of 228 mL.



identified. This technique does not provide good imaging of the prostatic and membranous urethra and should not be utilized for this purpose. However, the entire bulbar and penile urethra is depicted with excellent detail and accuracy.

The largest discrepancy between the RUG and ultrasonography for urethral stricture is in regard to the bulbar urethra. This segment of the urethra lies in an oblique position relative to the axis of the X-ray beam, whereas the ultrasound transducer is in the same axis as the urethra. This situation makes strictures of the bulbar urethra appear shorter on the RUG than they really are. Thus, basing an operative decision on the preoperative RUG can leave the surgeon needing to use a free graft more readily than anticipated. Nash and colleagues[10] found that information obtained from the ultrasound scan changed the planned reconstructive procedure in 16% of their patients with anterior urethral structures (Fig. 2).

Ultrasonography also detects the amount of periurethral fibrosis, which may be the most important prognostic factor in reconstructive surgery of the urethra. Some urologists advocate that if a substantial amount of periurethral fibrosis is encountered prior to internal urethrotomy, an open urethroplasty should be considered as first-line therapy.[11] Lastly, ultrasonography can detect urethral calculi, diverticula, and false passages.[7]

Color Doppler ultrasonography has been helpful to determine the anatomic position of the arteries in the bulbar urethra[12,13] while maintaining the capability to evaluate stricture length. The preoperative localization of the urethral arteries has been thought to be helpful in avoiding excessive bleeding with visual internal urethrotomy. The classic teaching is that the urethral arteries are located at 3 and 9 o'clock in the bulbar urethra, so incising at the 12 o'clock, 10 o'clock, or 2 o'clock positions should be possible. However, Chiou and coworkers[12] found great variability in arterial location. Arteries were found 40% of the time at the 3 o'clock and 9 o'clock position, whereas in 25%, they were at the 1 o'clock to 2 o'clock and 11 to 12 o'clock positions. Color Doppler study also aids in discerning the blood flow to the corpus spongiosum.[13]

## BLADDER ULTRASONOGRAPHY FOR DETERMINATION OF POSTVOIDING RESIDUAL VOLUMES

Urethral catheterization is the gold standard for the measurement of postvoiding residual (PVR) urine volume.[14] However, there are some concerns about the risk of infection, discomfort for the patient, and accuracy of these measurements.[15] Catheter studies have been found to be inaccurate in determining PVRs in as many as 26% of patients, with differences in volume of as much as 52 mL.[15]

Imaging of the bladder with ultrasound has been abundantly described, first with large, departmentally confined machines. But the 1990s have seen the advent of small, portable ultrasound machines becoming the norm in the urologist's office.

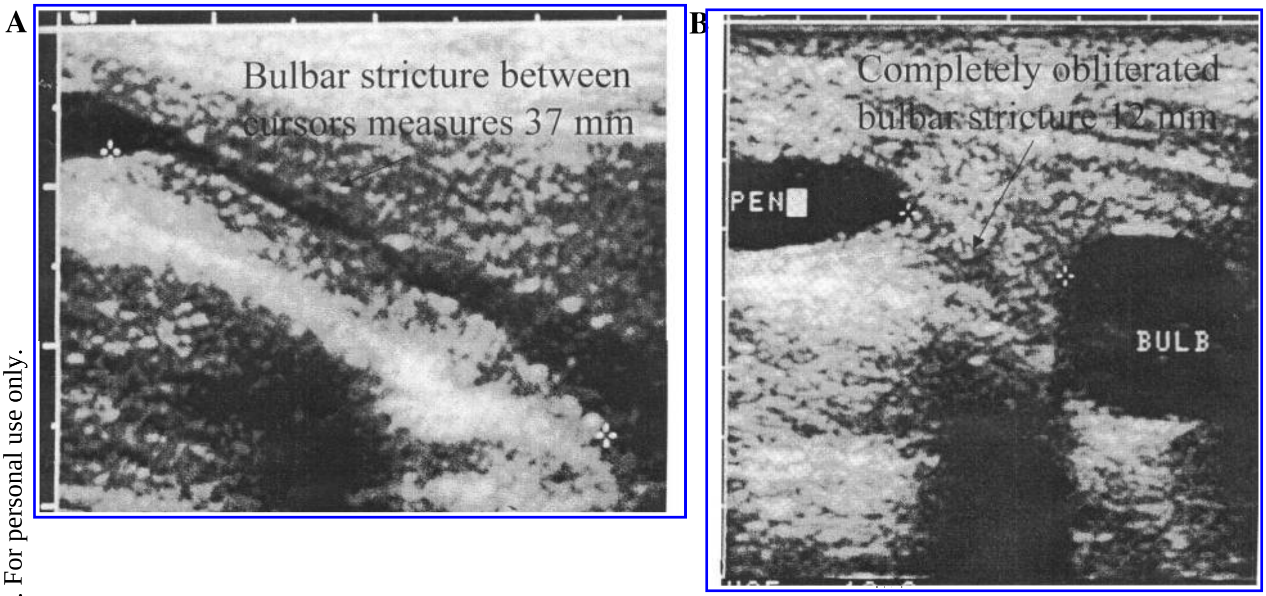


**FIG. 2.** Sonourethrography of two bulbar strictures. (Reprinted with permission from McAninch JA, Morey AF. Ultrasound evaluation of the male urethra for assessment of urethral stricture. J Clin Ultrasound 1996;24:473–479.)

They are a quick, simple, painless, and an accurate means to determine the PVR. Coombes and Millard[14] compared portable ultrasound PVRs with catheter PVRs and found ultrasound to be as reliable as standard determinations.

Because the bladder is positioned in the pelvis and can easily be distended with fluids, it can be well seen with ultrasound scans. Bladder ultrasonography is not limited to determining PVRs but has also been found useful in discerning the size and location of bladder diverticula, radiolucent calculi, and neoplasms. There have also been reports of using intraluminal ultrasound for the staging of bladder neoplasms, but this method has not gained widespread acceptance and is confined to a few medical centers with the appropriate imaging instruments.[16]

## GRAY-SCALE AND COLOR DOPPLER ULTRASONOGRAPHY FOR VARICOCELE EVALUATION

The role of varicoceles in male infertility has been studied since the late 19th century.[17] Macleod[18] observed the particular semen qualities associated with varicoceles, including decreased sperm concentration and motility and increased numbers of sperm with abnormal morphology. Charney[19] reported the improvement in semen quality after surgical correction of varicoceles. Tulloch[20] stimulated interest in varicocelectomy for male infertility by reporting a pregnancy in the partner of an azoospermic patient after bilateral varicocele ligation. Now, many investigators have reported the benefits of varicocelectomy in improving semen characteristics.[21,22]

Varicoceles, identified by physical examination, are reported to occur in 8% to 22.9% (mean 13.4%) of the general male population with no known fertility problems.[23] The incidence of varicocele is higher in the infertile population, approaching 37%.[23] The most common method of determining the presence of a varicocele is physical examination.[24] However, physical examination is subjective and dependent on the examining physician, although it is easily performed, inexpensive, and noninvasive.

Demas and colleagues[25] described diagnostic gray-scale sonographic criteria for varicoceles. A scan should demonstrate two or more veins, one with a diameter >3 mm and increasing in size with standing or Valsalva maneuver. Subclinical varicoceles (<3 mm in diameter) are difficult to palpate even with Valsalva maneuvers, yet have a role in subfertility, such that

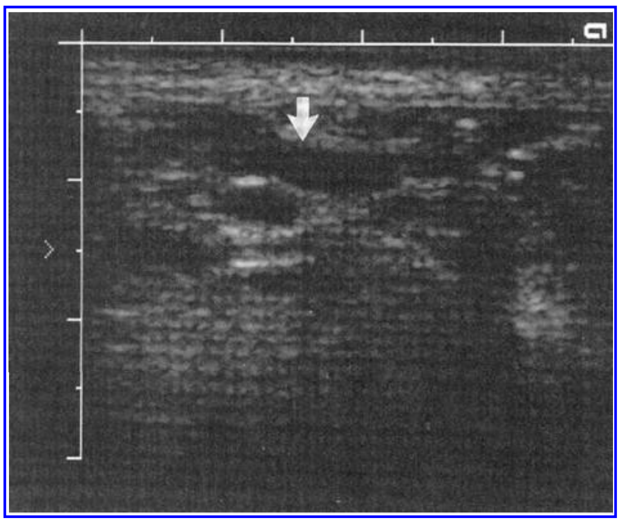

**FIG. 3.** Longitudinal image of lower spermatic cord superior to left testis. Hypoechoic linear structure (arrow) represents dilated vein. (Reprinted with permission from Meacham RB, Townsend RR, Rademacher D, Drose JA: The incidence of varicoceles in the general population when evaluated by physical examination, gray scale sonography and color Doppler sonography. J Urol 1994;151:1535–1538.)

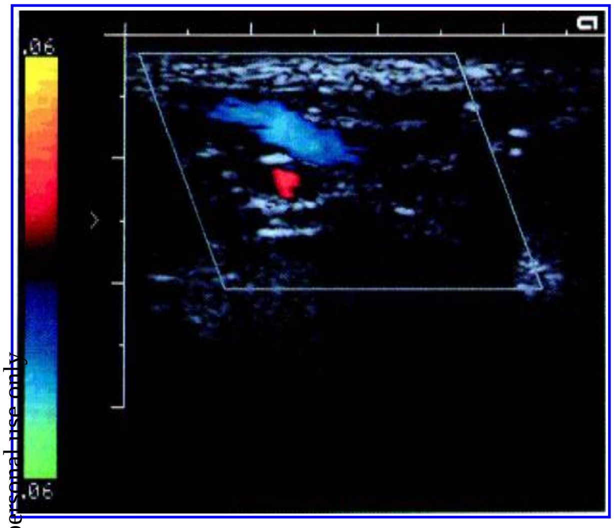

**FIG. 4.** Color Doppler image demonstrates retrograde (blue; away from transducer) flow with dilated vein. (Reprinted with permission from Meacham RB, Townsend RR, Rademacher D, Drose JA: The incidence of varicoceles in the general population when evaluated by physical examination, gray scale sonography and color Doppler sonography. J Urol 1994;151: 1535–1538.)

surgical correction may benefit patients.[26,27] The pathophysiology of varicoceles is also controversial. The critical feature is believed to be incompetent valves within the gonadal vein.[28] This valvular incompetence results in retrograde flow through the gonadal vein that becomes exacerbated with standing or increased intra-abdominal pressure (Valsalva maneuver).

Venography is the most accurate imaging modality to determine retrograde flow through the gonadal vein, but it is invasive and expensive. Recently, attention has been given to noninvasive imaging modalities for determining retrograde flow in the gonadal veins with color Doppler. Petros and colleagues[29] found color Doppler sonography to be more accurate than physical examination for detecting a varicocele and recommended its use to avoid more invasive imaging and therapy. Color Doppler scanning provides the urologist with more physiological information because it actually measures retrograde venous flow rather than simply venous diameter.[24] Patients with normal-diameter gonadal veins but abnormal flow can now be identified with a quick, accurate, and noninvasive modality. Petros and colleagues[29] considered the finding of retrograde flow within the pampiniform plexus by color Doppler sonography to define a varicocele regardless of its diameter. Meacham and associates[24] found 35% of their study population to have retrograde flow through the pampiniform plexus. Among 26 patients with normal semen characteristics, 31% had demonstrable retrograde flow. This result demonstrates the ability of color Doppler studies to detect varicoceles in patients with normal physical examination and a negative gray-scale sonographic examination. Still, only a third of their patients had a positive color Doppler examination. This result may support the view that only a small subset of normally fertile patients will have retrograde flow (Figs. 3 and 4).

## DOPPLER IMAGING FOR EVALUATING VASCULOGENIC IMPOTENCE

Erectile dysfunction is associated with cavernosal arterial disease or corporeal veno-occlusive dysfunction.[30,31] Intracavernosal pharmacotherapy and new oral medications have enabled the medical treatment of impotence while facilitating diagnostic evaluation of the arterial inflow or veno-occlusive mechanism. A duplex ultrasound evaluation of the arterial inflow after pharmacotherapy has been used to describe the hemodynamic events with tumescence.[31–34] Duplex ultrasonography can identify abnormal cavernosal arterial inflow by measuring peak systolic velocity.[32,34] It also permits indirect measurement of the veno-occlusive mechanism by measuring the cavernosal artery end-diastolic velocity.[32–34] Color flow duplex ultrasonography permits accurate delineation of the penile arterial and cavernosal anatomy. However, color Doppler analysis does not allow the detection of flow in the distal ramifications of the cavernosal arteries (helicine arterioles). Recently, a new type of color Doppler ultrasonography, called power Doppler, has enabled the determination of flow through the helicine arteries.[35,36]

Angiography has been considered the standard method for

A B C

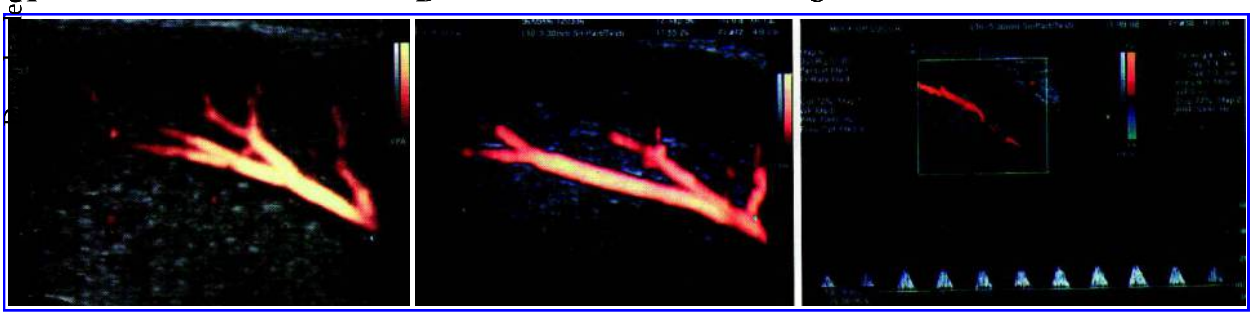

**FIG. 5.** Evaluation of erectile impotence. (**A**) Power Doppler sonography of normal cavernous arteries. Ramifications from main trunk have oblique course and uniform caliber. (**B**) Proximal arterial damage. (**C**) Pulsed power Doppler sonography with progressive increase in intracavernous pressure. (Reprinted with permission from Sarteschi LM, Montorsi F, Fabris FM, et al. Cavernous arterial and arteriolar circulation in patients with erectile dysfunction: A power Doppler study. J Urol 1998;159: 428–432.)

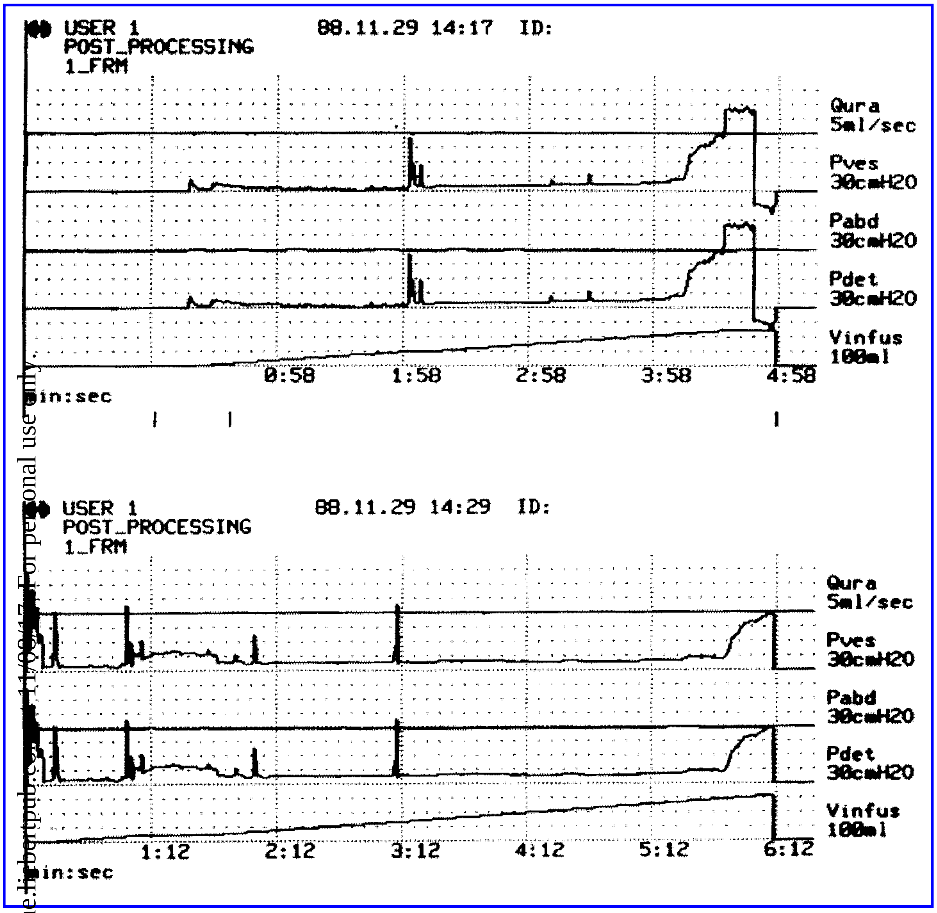


**FIG. 6.** Cystometrograms recorded via double-lumen catheter (top) and flexible cystoscope (bottom). (Reprinted with permission from Douenias R, Rich MA, Badlani GH: Endourodynamics: A new method for evaluation of bladder function. J Endourol 1990;4:117–121.)

the determination of vasculogenic impotence amenable to surgical correction. However, only the main tributaries of the dorsal and cavernosal arteries can be delineated.[37] Pudendal angiography is an invasive imaging method that places the patient at risk of an anaphylactic reaction and is too costly to use for screening.

Power Doppler sonography is founded on the integrated Doppler power spectrum.[38] The brightness of the Doppler reading is dependent on the number of red blood cells producing the Doppler shift. Power Doppler is angle independent, and background noise is displayed so that it increases the usable dynamic range of the scans, allowing the identification of the small helicine arteries. Sarteschi and coworkers[38] were able to detect cavernosal arterial inflow in the flaccid state using power Doppler in patients with nonvasculogenic and vasculogenic impotence. Helicine arterial inflow was not detected in the flaccid organ, suggesting that the microcirculation is not important during this hemodynamic state. With an intracavernosal al-

A B

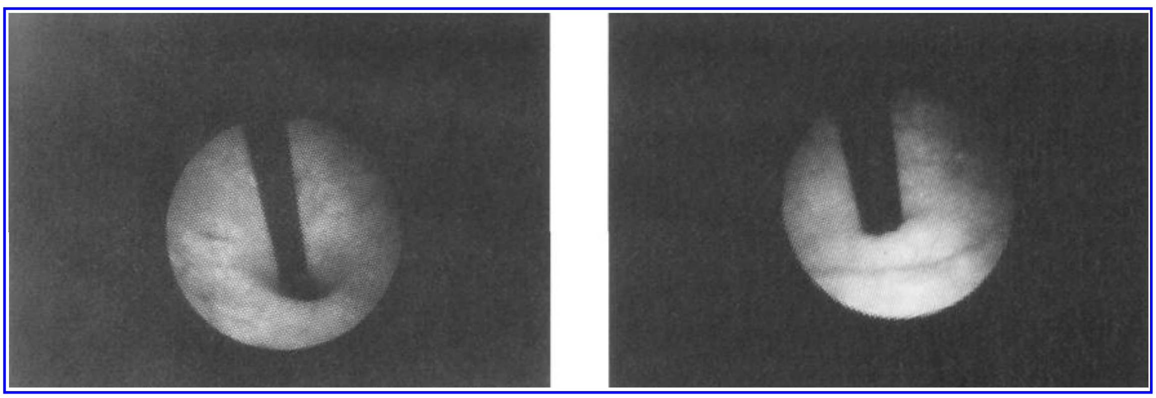

**FIG. 7.** Funneling of bladder neck and return to original position. (Reprinted with permission from Douenias R, Rich MA, Badlani GH. Endourodynamics: A new method for evaluation of bladder function. J Endourol 1990;4:117–121.)

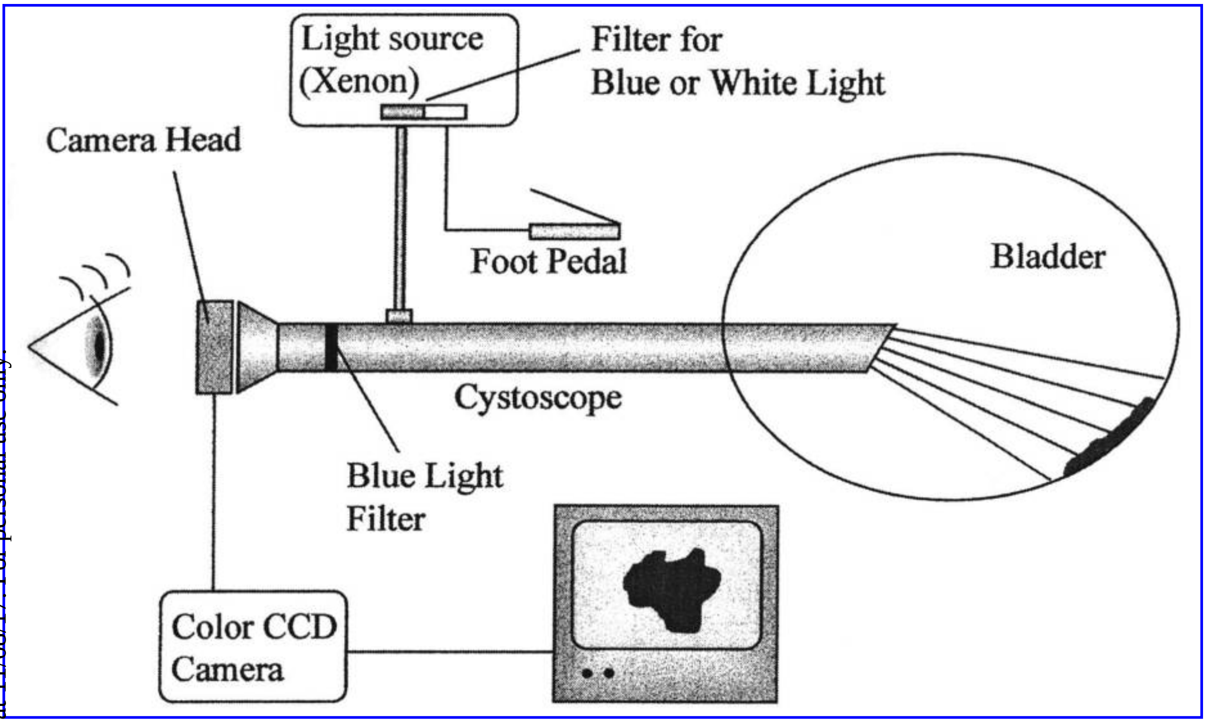


**FIG. 8.** Fluorescence viewing set-up. Blue light filter in cystoscope was used to block most of blue excitation light. (Reprinted with permission from Koenig F, McGovern FJ. Fluorescence detection of bladder carcinoma. Urology 1997;50: 778–779.)

prostadil injection, the anatomic detail of the cavernosal arteries became apparent, demonstrating differences between the arteriogenic and nonarteriogenic disorder. The irregularities noted were a decrease in diameter (although it was not statistically significant), irregularities of the arterial wall, and a reduction in pulsatility. These differences were accentuated compared with findings on regular color Doppler scans.

Helicine arterial anatomy was different in the two study groups. Patients with normal power Doppler results all demonstrated three orders of helicine arterioles that originated from the cavernous artery, forming an acute angle. The arteriole wall was regular and pulsatile (Fig. 5). Among patients with vasculogenic impotence and normal cavernous arteries, 50% demonstrated a reduced number of helicine ramifications, usually only

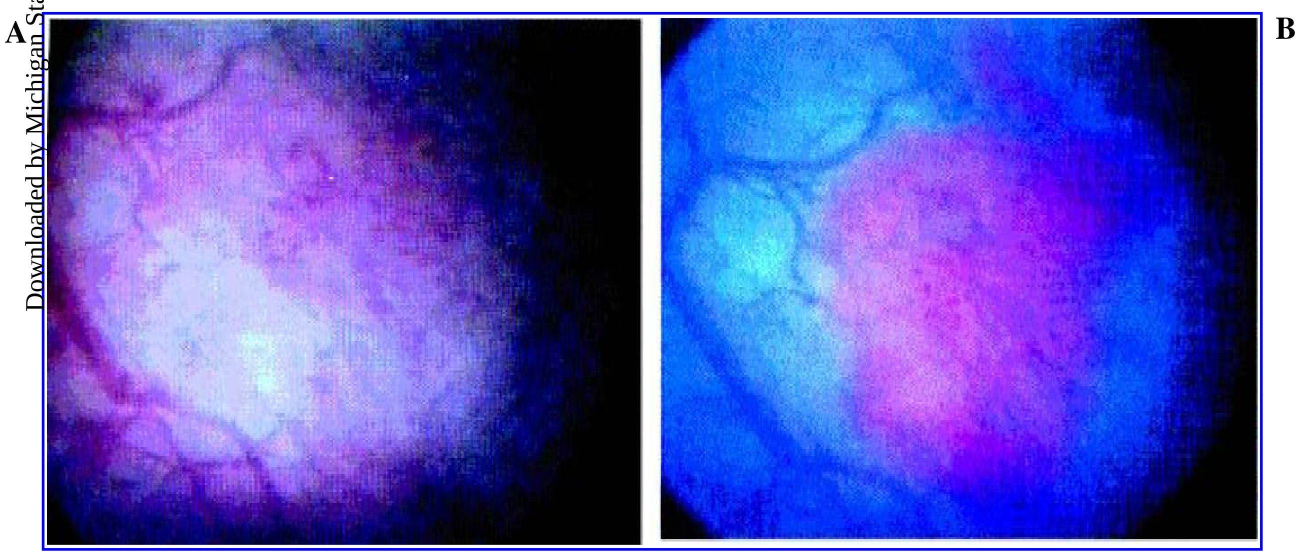


**FIG. 9.** Utility of fluorescence imaging. (**A**) Conventional white light image. (**B**) Fluorescence image using blue light excitation. (Reprinted with permission from Koenig F, McGovern FJ. Fluorescence detection of bladder carcinoma. Urology 1997;50:778–779.)

one (normal = three) after alprostadil injection, which had a tendency to leave the cavernous artery at right angles and to have an irregular caliber. These patients were unable to reach rigid tumescence and had Doppler features indicative of veno-occlusive disease. Of the patients with cavernous arteries and helicine arteriole disease, none was able to achieve rigid tumescence, and all had veno-occlusive dysfunction.

Those investigators categorize patients into three groups: (1) proximal arterial damage; (2) global arterial and arteriolar damage; and (3) predominantly arteriolar damage. With proximal arterial damage (common iliac, hypogastric, internal pudendal, and common penile arteries), the peak systolic velocity in the cavernous artery is reduced, acceleration time is increased, and acceleration is decreased. Power Doppler scans will illustrate cavernous arteries with uniform caliber and helicine arterioles that are regular in disposition with normal caliber and ramifications. In these patients, the cavernous and helicine arterioles are preserved so that the veno-occlusive mechanism may still be functional in the initial phase, allowing the patient to achieve tumescence. In global arterial and arteriolar damage, all Doppler parameters are abnormal, demonstrating reduced cavernous arterial diameter, irregular caliber, and thinned and irregular-appearing helicine arterioles and first-order ramifications. Penile tumescence is not achieved in these patients. With arteriolar damage, cavernous Doppler parameters are normal. However, the arteriolar component demonstrates irregular caliber, decreased number of ramifications, and branches from the cavernous arteries at right angles. This pathology is evident in diabetic patients.

Power Doppler allows more precise determination of the morphology of the cavernous and helicine arterioles. The arterial and arteriolar morphologic changes discussed may explain the poor results obtained with penile revascularization procedures.

## ENDOURODYNAMICS

Flexible cystoscopy was first described by Tsuchida and Sugawara in 1973.[39] This technique of examination has now been utilized by urologists to perform office cystoscopy, bedside cystoscopy in critically ill patients, retrograde pyelography, biopsy and fulguration of tumors, placement of ureteral stents with fluoroscopic guidance, and urodynamic studies.[40–43]

Loughlin and Yalla in 1986[40] combined flexible cystoscopy and urodynamics, becoming the first to describe endourodynamics. They recorded urethral pressure profiles (UPP) using a flexible cystoscope to aid in determining the urethral location of the pressure sensor during micturition. With their specially designed flexible cystoscope by Olympus, they conducted fluid bridge tests and micturitional total pressure determinations. The standard flexible cystoscope could not be used to measure UPP because the opening of the working port is at the distal end, not on its lateral aspect as needed. Douenias and colleagues[45] demonstrated that endourodynamics gives reliable and accurate results. It allows assessment of the bladder neck during micturition (Figs. 6 and 7). This study is particularly useful in patients with detrusor neck dyssynergia, Parkinson's disease, multiple sclerosis, or Shy-Drager syndrome. It is often difficult to diagnose bladder neck dyssynergia without sophisticated VUDS. Endourodynamics may be the alternative, providing similar information without the need for fluoroscopy.

Chancellor and coworkers[44] have incorporated endourodynamics into the evaluation of patients with spinal cord injury because the examination can be performed easily and accurately without moving the patient from the wheelchair. This saves time and money and reduces patient discomfort. Douenias and associates,[45] who used endourodynamics in lieu of videourodynamics and cystoscopy, showed reduced procedure time, cost, and urethral manipulation. It is recommended to measure cystometric pressure initially, as overdistention during cystoscopy may result in an inaccurate measurement. Today, the indications for endourodynamics are incontinence after radical prostatectomy, as stricture commonly coexists, and minimally invasive therapy for prostatism where the presence of a medium or large middle lobe is a contraindication for microwave thermotherapy or prostate stent therapy.

## PHOTODYNAMIC THERAPY WITH AMINOLEVULINIC ACID FOR SUPERFICIAL BLADDER TRANSITIONAL-CELL CARCINOMA

Integral photodynamic therapy (PDT) is an investigational treatment for cancer that works by generating a reactive oxygen molecule through the interaction of light and a photosensitizing chemical.[46] Aminolevulinic acid has received attention as a possible photosensitizing agent and is currently undergoing clinical trials for both superficial bladder and skin cancers.[47,48] This chemical is an initial substrate of heme biosynthesis, and when it is administered, epithelial tissues accumulate endogenous protoporphyrin IX. It is hoped by administering this medication intravesically instead of intravenously, as with prior photosensitizing agents, that photosensitization of the skin and the risk of damaging bladder muscle leading to bladder shrinkage can be avoided.[47]

Kriegmair and colleagues[47] reported the use of PDT with intravesical ALA for recurrent superficial bladder cancer. Their experience encompassed 10 patients, all of whom had received multiple transurethral resections, intravesical mitomycin C, and subsequent BCG. Radical cystectomy was indicated in all patients because of extensive superficial cancer covering the bladder wall, which could not be resected safely. Four patients had concomitant carcinoma *in situ*. The PDT was performed after intravesical instillation of ALA in an attempt at bladder salvage. The average functional bladder capacity was 335 mL, and clinical staging by CT scan of the abdomen and pelvis, along with a bone scans, suggested that all patients had organ-confined disease.

The bladder cancers were photosensitized by the intravesical instillation of 5 g of ALA hydrochloride (Merck, Darmstadt, Germany) dissolved in 30 mL of sodium bicarbonate. The duration of instillation ranged from 4.7 to 8.3 hours (mean 5.1 hours). Light was applied from an argon-pumped dye laser with red and green continuous-wave light with a wavelength of 635 nm (Figs. 8, 9). Isotonic saline was used as cystoscopic irrigant during the photosensitization. The response was evaluated at 10 to 12 weeks after the procedure with cystoscopy, random biopsies, and urine cytology.

In the months following PDT, a total of five patients had disease advancement and underwent radical cystectomy. The rate of positive biopsy before and after PDT was 62.5% and 18.8%, respectively. In three of four patients with moderately or poorly differentiated papillary tumors and concomitant carcinoma *in situ*, there was either a complete or a partial response, whereas only three of the six patients with well- or moderately differentiated tumors and concomitant carcinoma *in situ* had an adequate response. Although there was no protection by the patients against exposure to light, there were no phototoxic skin reactions. After PDT, all 10 patients complained of dysuria, which persisted for as long as 4 weeks in some patients. Six patients complained of gross hematuria and passing of desquamated tissue. There was no decrease in bladder capacity and no fibrosis of the submucosa or bladder muscle in all repeated biopsy or cystectomy specimens. It is also to be noted that *in vivo* spectral measurements demonstrated a 10-fold greater fluorescence of papillary tumors than of normal urothelium. It appears that PDT with ALA has a promising future as an alternative therapy for bladder cancer with few side effects.

## DYNAMIC FAST MRI FOR PELVIC PROLAPSE

Pelvic prolapse is a common malady in multiparous women between the ages of 45 and 56 years, often after hysterectomy, with a reported prevalence approaching 16%.[50–52] The symptoms of pelvic floor prolapse include pain, urinary or fecal incontinence, hemorrhoids, and constipation.[53] The major risk factors for pelvic floor relaxation are age, obesity, chronic cough, and multiparity,[54] obviously conditions that may lead to consistently elevated intra-abdominal pressure.

Along with understanding the symptoms and causes of pelvic relaxation, the surgeon will need to appreciate and document the severity and pelvic compartment involved because the type of and anatomic approach for surgical intervention can differ widely.[55] The physical examination of the anterior, middle, and posterior compartments may be difficult, especially in obese women or severe prolapse, and may not be reliable or even reproducible between examiners.[53] There are numerous radiologic evaluations possible, including bead-chain cystometrography, videourodynamics, sonography, vaginography, and

A B

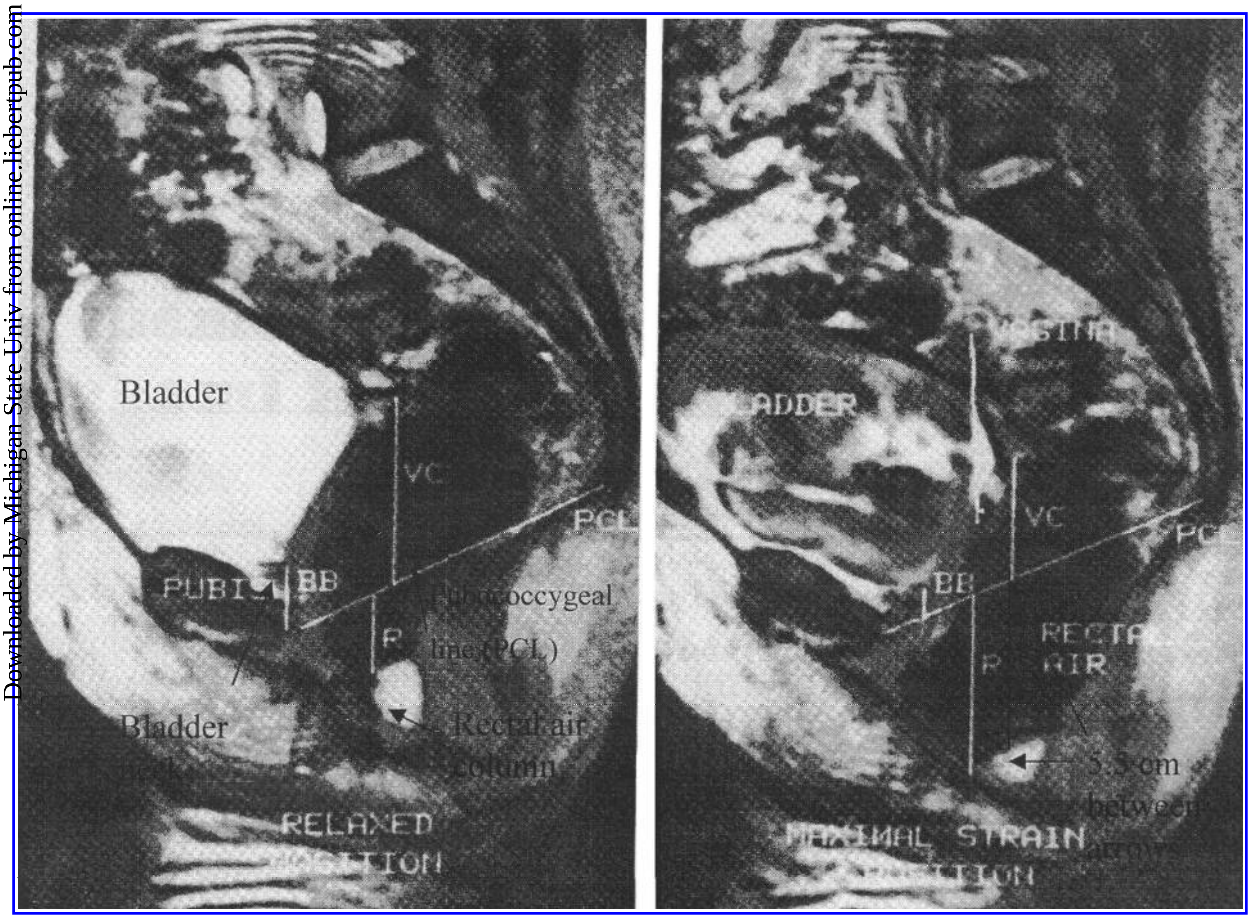


**FIG. 10.** Sagittal dynamic MR images of woman with urinary and fecal incontinence. (**A**) Relaxed. (**B**) During maximum strain. Vertical distance from pubococcygeal line to rectal air column is 5.5 cm, demonstrating rectocele. (Reprinted with permission from Yang A, Mostwin JL, Rosenshein NB, et al. Pelvic floor descent in women: Dynamic evaluation with fast MR imaging and cinematic display. Radiology 1991;179:25–33.)

barium defecography.[56–58] Unfortunately, none of these provides a representation of all three compartments. These studies are also uncomfortable and expose the patient to high radiation exposure from both fluoroscopy and radiography.[55] The relatively high failure rate of surgical therapy in creating symptomatic improvement and preventing recurrent prolapse suggests that these preoperative imaging modalities are inaccurate or inadequate.[59]

Recently, fast-sequence dynamic MRI has shown promise of delivering accurate images of these three compartments without ionizing radiation (Figs. 10 and 11).[55] Yang and associates[55] examined 26 patients with dynamic MRI for pelvic prolapse and 16 control patients without pelvic relaxation for other gynecologic reasons such endometriosis. They used the imaginary pubococcygeal line (PCL) as their frame of reference to discern the features of the prolapsed component. The limits of descent with maximal strain were defined as 1 cm below the PCL for the bladder base, 1 cm above for the vaginal cuff or end of the cervix, and 2.5 cm below for the rectal air column. The dynamic MRI study enhanced the information from two patients in regard to the anterior compartment, two the middle, and four the posterior compartment. There was no statistical difference in the resting position between the control, clinically negative, and clinically positive patients in any compartment, suggesting that static images without dynamic imaging may be inadequate to aid in diagnosis. Yang and coworkers felt that another advantage of dynamic MRI was in the detection of enteroceles. A defect in Denonvilliers' fascia or in the rectovaginal



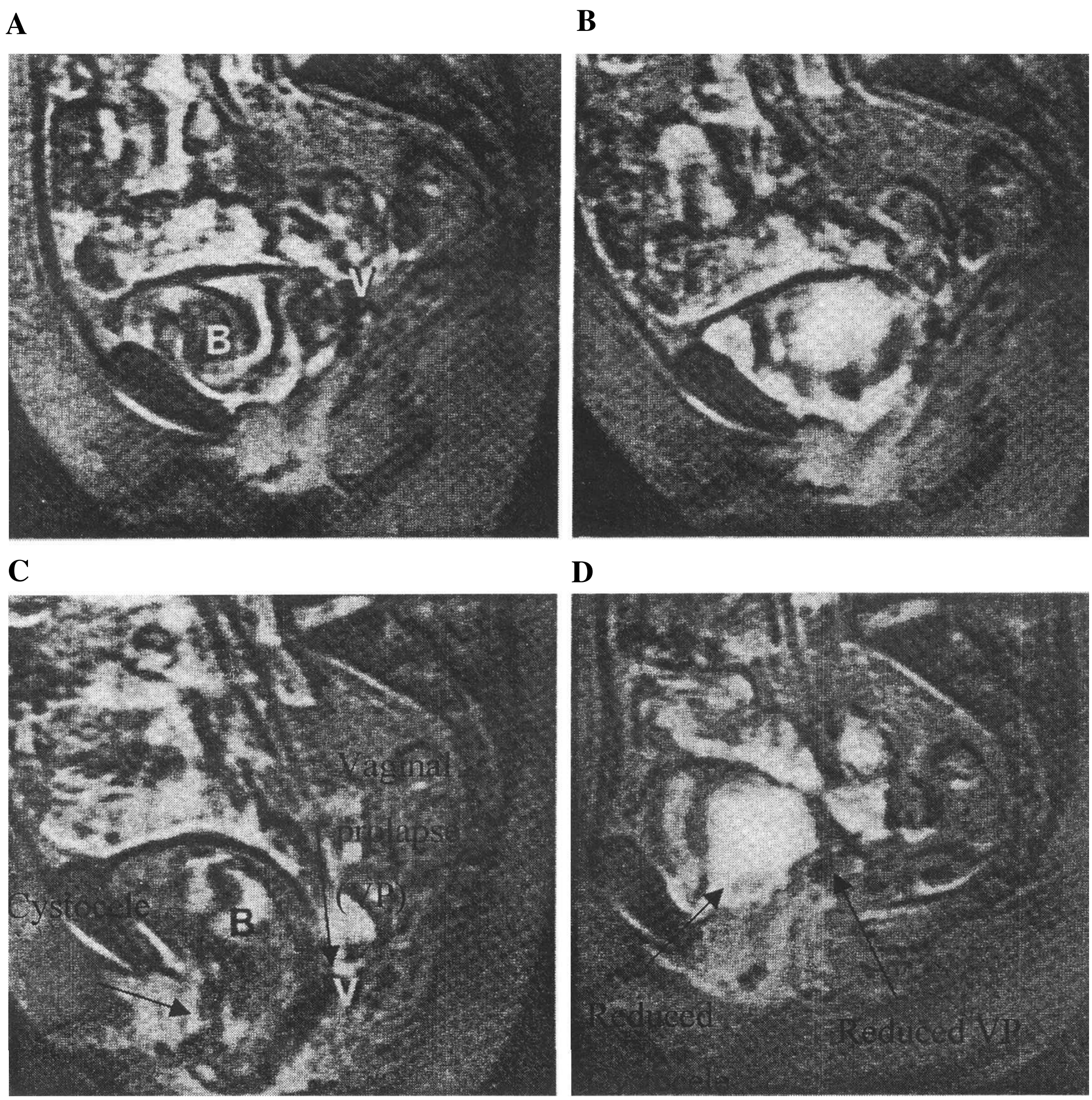


**FIG. 11.** Sagittal dynamic MR images of postmenopausal woman with stress urinary incontinence. (**A**) Bladder (B) and vaginal (V) positions without strain. (**B**) Positions during mild strain. Note small cystocele and vaginal prolapse. (**C**) Positions during strong abdominal straining. Note pronounced cystocele and vaginal vault prolapse (VP). (**D**) Prolapsed organs are completely reduced. (Reprinted with permission from Yang A, Mostwin JL, Rosenshein NB, et al. Pelvic floor descent in women: Dynamic evaluation with fast MR imaging and cinematic display. Radiology 1991;179:25–33.)

septum may become more readily apparent on dynamic MRI because of the mesenteric or retroperitoneal fat in these defects. The authors commented on how important it is to give precise instructions to the patient in regard to the stepwise pelvic strain (mild, moderate, and maximum) and perineal contraction. This improves the reproducibility of each examination. These graded steps allow cinematic display of resting and dynamic images of the temporal and spatial positions of the prolapsed organs.

It appears that dynamic MRI has few disadvantages. The ones noted are cost, inability to obtain urodynamic parameters such as detrusor instability simultaneously, and the variability of the rectal air column, leading to underestimation of the posterior compartment defect. However, with the use of gadolinium dimeglumine pentetate, this problem can be avoided.

Dynamic MRI is a fast and accurate but costly imaging modality, so questions about when to use it are becoming apparent. Yang and coworkers[55] suggest its utilization when: (1) patients with incontinence or other symptoms of prolapse have equivocal urodynamic or physical examination results; (2) there is recurrent prolapse or incontinence; (3) for follow-up examinations in patients followed conservatively; (4) for suspected enterocele or multicompartment prolapse; (5) in patients unable to tolerate contrast or radiographic procedures; (6) in children with imperforate anus prior to reconstruction; and (7) as a research tool to define the biomechanics of prolapse. We can foresee the urologist, urogynecologist, and pelvic surgeon utilizing dynamic MRI as an adjunct to the physical examination and radiologic studies when clinical questions have not been answered.

## CONCLUSIONS

Imaging of the lower urinary tract is now multidimensional, including videourodynamics; gray-scale/color Doppler ultrasonography of the urethra, penile, and testicular vasculature; endourodynamics; and dynamic MRI. These modalities are in some instances becoming office based and being utilized with more frequency. They facilitate a quick, accurate, and reproducible diagnosis. Cost can be prohibitive and a limiting factor, but the proper instances for their utilization are now becoming apparent.

## ACKNOWLEDGMENT

I dedicate this paper to my mother, Elsa Marinkovic, and my wife, Annette. Their encouragement and support through residency and two fellowships have made my academic career possible. Thank you.

## REFERENCES

1. McGuire EJ, Fitzpatrick CC, Wan J, et al. Clinical assessment of urethral sphincter function. J Urol 1993;150:1452–1456.
2. McGuire EJ, Cespedes D, Cross CA, O'Connell HE. Videourodynamic studies. Urol Clin North Am 1996;23:309–321.
3. McGuire EJ, Woodside JR. Diagnostic advantages of fluoroscopic monitoring during urodynamic evaluation. J Urol 1981;125: 830–833.
4. McGuire EJ, Woodside JR, Borden TA, et al. Prognostic value of urodynamic testing in myelodysplasia patients. J Urol 1981;126: 205–209.
5. Ghoniem GM, Walters F, Lewis V. The value of the vaginal pack test in large cystoceles. J Urol 1994;152:931–934.
6. McAninch JA, Laing FC, Jeffrey B Jr. Sonourethrography in the evaluation of urethral strictures: A preliminary report. J Urol 1988;139:294–297.
7. McAninch JA, Morey AF. Ultrasound evaluation of the male urethra for assessment of urethral stricture. J Clin Ultrasound 1996;24: 473–479.
8. McAninch JA, Morey AF. Role of preoperative sonourethrography in bulbar urethral reconstruction. J Urol 1997;158:1376–1379.
9. Heidenreich A, Derschum W, Bonfig R, Wilbert DM. Ultrasound in the evaluation of urethral stricture disease: A prospective study in 175 patients. Br J Urol 1994;74:93–98.
10. Nash PA, McAninch J, Bruce JE, Hanks DK. Sonourethrography in the evaluation of anterior urethra strictures. J Urol 1995;154: 72–76.
11. Merkle W, Wagner W. Risk of recurrent stricture following internal urethrotomy: Prospective ultrasound study of the distal urethra. Br J Urol 1990;65:618–620.
12. Choiu RK, Donovan JM, Anderson JC, et al. Color Doppler ultrasound assessment of urethral arterial location: Potential implication for technique of visual internal urethrotomy. J Urol 1998;159: 796–799.
13. Choiu RK, Anderson JC, Tran T. Evaluation of urethral strictures and associated abnormalities using high-resolution and color Doppler ultrasound. Urology 1996;47:102–107.
14. Coombes GM, Millard RJ. The accuracy of portable ultrasound scanning in the measurement of residual urine volume. J Urol 1994;152:2083–2085.
15. Stoller ML, Millard RJ. The accuracy of catheterized residual urine. J Urol 1989;141:15–18.
16. Bodner DR, Resnick ML. Ultrasound of the urinary bladder. In: Resnick ML, Rifkin MD (eds): Ultrasound of the Urinary Tract, ed 3. Baltimore: Williams & Wilkins, 1991, pp 250–281.
17. Zorgniotti A. The spermatozoa count: A short history. Urology 1975;5:673–676.
18. Macleod J. Seminal cytology in the presence of varicocele. Fertil Steril 1965;16:735–738.
19. Charney CW. Effect of varicocele on fertility: Results of varicocelectomy. Fertil Steril 1962;13:47–51.
20. Tulloch WS. Varicocele in subfertility: Results of treatment. Br Med J 1955;2:356–360.
21. Marks JL, McMahon R, Lipshultz LI. Predictive parameters of successful varicocele repair. J Urol 1986;136:609–613.
22. Jarow JP, Ogle SR, Eskew LA. Seminal improvement following repair of ultrasound detected subclinical varicoceles. J Urol 1996;155:1287–1290.
23. Lipshultz LI, Jarow JP. Varicocele and male subfertility. In: Sciarra JJ (ed): Gynecology and Obstetrics, vol 5. Philadelphia: JB Lippincott, 1989, pp 1–12.
24. Meacham RB, Townsend RR, Rademacher D, Drose JA. The incidence of varicoceles in the general population when evaluated by physical examination, gray scale sonography and color Doppler sonography. J Urol 1994;151:1535–1538.
25. Demas BE, Hricak H, McClure RD. Varicoceles: Radiologic diagnosis and treatment. Radiol Clin North Am 1991;29:619–623.
26. McClure RD, Hricak H. Scrotal ultrasound in the infertile man: Detection of subclinical unilateral and bilateral varicoceles. J Urol 1986;135:711–714.
27. McClure RD, Khoo D, Jarvi K, Hricak H. Subclinical varicocele: The effectiveness of varicocelectomy. J Urol 1991;145:789–793.
28. Brown JS, Dubin L, Becker L, Hotchkiss RS. Venography in the subfertile man with varicocele. J Urol 1967;98:388–391.

29. Petros JA, Andriole GL, Middleton WD, Piscus DA. Correlation of testicular color Doppler ultrasonography, physical examination and venography in the detection of left varicoceles in men with infertility. J Urol 1991;145:785–790.
30. Krane RJ, Goldstein I, Saenz de Tejada I. Medical progress—Impotence. N Engl J Med 1989;321:1648–1651.
31. Shabsigh R, Fishman IJ, Quesada ET, Seale-Hawkins CK, Dunn JK. Evaluation of vasculogenic impotence using penile duplex ultrasonography. J Urol 1989;142:1469–1471.
32. Bassiouny HS, Levine LA. Penile duplex sonography in the diagnosis of venogenic impotence. J Vasc Surg 1991;13:75–81.
33. Levine LA, Coogan CL. Penile vascular assessment using color duplex sonography in men with Peyronie's disease. J Urol 1996;155:1270–1274.
34. Lue TF, Mueller SC, Jow YR, Hwang TI. Functional evaluation of penile arteries with duplex ultrasound in vasodilator-induced erection. Urol Clin North Am 1989;16:799–805.
35. Bude RO, Rubin JM, Adler RS. Power versus conventional color Doppler sonography: Comparison in the depiction of normal intrarenal picture. Radiology 1994;192:777–781.
36. Rubin JM, Bude RO, Carson PL, Bree RL, Adler RS. Power Doppler US: A potentially useful alternative to mean frequency based color Doppler US. Radiology 1994;190:853–857.
37. Vickers KE, Vickers MA. Has the efficacy of penile arterial bypass surgery in the treatment of arteriogenic erectile function been determined? Int J Impotence Res 1996;8:247–251.
38. Sarteschi LM, Montorsi F, Fabris FM, et al. Cavernous arterial and arteriolar circulation in patients with erectile dysfunction: A power Doppler study. J Urol 1998;159:428–432.
39. Tsuchida S, Sugawara H. A new flexible fibercystoscope for visualization of the bladder neck. J Urol 1973;109:830–831.
40. Loughin KR, Yalla SV. Endourodynamics: Another valuable dimension in clinical urodynamics. Neurourol Urodyn 1986;5:291–298.
41. Powell PH, Manohar V, Ramsden PD, Hall RR. A flexible cystoscope. Br J Urol 1984;56:622–624.
42. Clayman RV, Kramolowsky EV. Bedside flexible cystoscopy: An approach to the critically ill patient. J Urol 1986;135:251–255.
43. Synder JA, Smith AD. Supine flexible flexible cystoscopy. J Urol 1986;135:251–254.
44. Chancellor MB, Rivas DA, Erhard MJ. Flexible cystoscopy during urodynamic evaluation of spinal cord-injured patients. J Endourol 1993;7:531–535.
45. Douenias R, Rich MA, Badlani GH. Endourodynamics: A new method for evaluation of bladder function. J Endourol 1990;4:117–121.
46. Weishaupt KR, Gomer CJ, Dougherty TJ. Identification of singlet oxygen as the cytotoxic agent in photo-inactivation of a murine tumor. Cancer Res 1976;36:2326–2329.
47. Kriegmair M, Baumgartner R, Lumper W, Waidelich R, Hofstetter A. Early clinical experience with 5 aminolaevulinic acid for the photodynamic therapy for superficial bladder cancer. Br J Urol 1996;77:667–671
48. Cairnduff F, Stringer MR, Hudson EJ, Ash DV, Brown SB. Superficial photodynamic therapy with topical 5 aminolaevulinic acid for superficial primary and secondary skin cancer. Br J Cancer 1985;69:605–608.
49. Koenig F, McGovern FJ: Fluorescence detection of bladder carcinoma. Urology 1997;50:778–779.
50. Hagstad A, Janson PO, Lindstedt G. Gynaecological history, complaints, and examinations in a middle aged population. Maturitas 1985;7:115–128.
51. Cruikshank SH. Preventing posthysterectomy vaginal vault prolapse and enterocele during vaginal hysterectomy. Am J Obstet Gynecol 1987;156:1433–1440.
52. Hording U, Pedersen KH, Sidenius K, et al. Urinary incontinence in 45 year old women: An epidemiological survey. Scand J Urol Nephrol 1986;20:183–186.
53. Healy JC, Halligan S, Reznek R, et al. Patterns of prolapse in women with symptoms of pelvic floor weakness: Assessment with MR imaging. Radiology 1997;203:77–81.
54. Goodrich MA, Webb MJ, King BF, et al. Magnetic resonance imaging of the pelvic floor: Dynamic analysis and evaluation of patients before and after surgical repair. Obstet Gynecol 1993;82:883–891.
55. Yang A, Mostwin JL, Rosenshein NB, et al. Pelvic floor descent in women: Dynamic evaluation with fast MR imaging and cinematic display. Radiology 1991;179:25–33.
56. Whitehead WE, Schuster MM. Anorectal physiology and pathophysiology. Am J Gastroenterol 1987;82:487–497.
57. Mahieu P, Pringot J, Bodart P. Defecography 1: Description of a new procedure and results in normal patients. Gastrointest Radiol 1984;9:247–251.
58. Mahieu P, Pringot J, Bodart P. Defecography II: Contribution to the diagnosis of defecation disorders. Gastrointest Radiol 1984;9:253–261.
59. Morley GW, Delancey JD. Sacrospinous ligament fixation for eversion of the vagina. Am J Obstet Gynecol 1988;158:872–881.

Address reprint requests to:
*Gopal H. Badlani, M.D.*
*Dept. of Urology*
*Northshore-Long Island Jewish Health Systems*
*New Hyde Park, NY 11040*

**This article has been cited by:**


1. Assunta Pizzi, Catiuscia Falsini, Monica Martini, Mario Alberto Rossetti, Sonia Verdesca, Aldo Tosto. 2013. Urinary incontinence after ischemic stroke: Clinical and urodynamic studies. *Neurourology and Urodynamics* n/a-n/a. [Crossref]
2. Steven S. Raman, Lousine Boyadzhyan. IMAGING OF THE FEMALE GENITOURINARY TRACT 86-99. [Crossref]
3. Laurence H. Stewart, John P. Brush. 2002. Magnetic resonance imaging for urinary incontinence. *Current Opinion in Urology* **12**:2, 133-136. [Crossref]