Application of Ultrasonography in Female Voiding Dysfunction

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ABSTRACT

Managing female voiding dysfunction is a challenge in clinical work. Moreover, the symptoms are non-specific and can be caused by a variety of disorders. A thorough evaluation, including physical examination, imaging studies, and urodynamic investigation of the lower urinary tract, is crucial for appropriate management. Ultrasonography has the advantages of being non-invasive, reproducible, without radiation exposure, and low cost. With the use of a high-resolution transducer, pelvic organs can be demonstrated clearly on ultrasonography. In addition, three-dimensional ultrasonography provides a clear demonstration of the spatial orientation of the female lower urinary tract. Both color and power Doppler scanning can not only reveal the vascular flow in pelvic organs, but also demonstrate urinary flow. Ultrasonography may help physicians explore the anatomic characteristics and pathophysiological mechanism of female outlet obstruction. In addition, it may assist in the surgical management of female voiding dysfunction with minimal invasion.

INTRODUCTION

Voiding dysfunction refers to problems relating to the functions of the bladder [1]. It may manifest as urine storage symptoms including frequency, urgency, nocturia, and urge incontinence, or emptying symptoms consisting of incomplete voiding, hesitancy, straining to void, urinary retention, and small urinary stream [1]. However, the symptoms are not specific to the etiologies of voiding dysfunction, which are often a challenge to verify [1] and are associated with successful management. The causes of voiding dysfunction can be differentiated as neurogenic or nonneurogenic [1]. The latter is frequently associated with bladder outlet obstruction, which may be functional or anatomical (Table 1) [1].

The prevalence of bladder outlet obstruction in women varied from 2.7% to 8%. [2]. Clinical evaluation usually comprises of history, physical examination, urinalysis, urodynamic studies, and cystourethroscopy. Ultrasonography has been widely applied in investigating female bladder outlet obstruction especially with the aid of high-resolution transducers, color and power Doppler angiography, and three-dimensional technology [3]. The aim of this article was to describe the advances in the application of ultrasonography in female bladder neck outlet obstruction, with the emphasis on anatomical factors.

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VOIDING DYSFUNCTION SECONDARY TO BLADDER CONDITIONS

Estimation of the bladder volume is important during initial investigations of female voiding dysfunction, and it can be made simply by either the transabdominal or transvaginal approach [3]. Using transabdominal ultrasonography, the bladder volume can be obtained using the following formula: bladder volume (mL) = H × D × W × 0.7, in which H, D, and W represent bladder height, bladder depth, and bladder width, respectively. Through transvaginal ultrasonography, the bladder volume can be calculated according to the formula: bladder volume (mL) = H × D × 5.9 - 14.6, with 95% confidence limits of around ± 37% [4].

Bladder calculi

Ultrasonography has the potential to detect bladder stones [3]. Bladder calculi account for 5% of urinary calculi and usually occur following foreign objects obstruction, or infections [5]. Anti-incontinence surgeries using nonabsorbable sutures predispose women with high risk for the development of bladder calculi. Transvaginal ultrasonography has been reported to successfully identify bladder stones and demonstrated retained hyperechoic sutures as the likely cause [5]. Because the retained sutures served as the nidus for crystallization, the contours were well demarcated on ultrasonography.

Bladder tumor (primary or metastatic)

Varying morphological features of bladder tumors on transabdominal ultrasonography have been reported, including: polypoid, sessile or plaque-like configuration; regular or irregular surface; and calcified or uncalcified texture [6]. Transvaginal ultrasonography with a high-

Table 1. Anatomic Causes of Bladder Outlet Obstruction in Women [1]

Inflammatory process	Obstetric/gynecologic condition
Inflammation of bladder neck	Retroverted gravid uterus
Inflammation of urethra	Retroverted uterus
Stenosis/stricture	Uterine tumor
Diverticulum	Cervical tumor
Abscess	Vaginal tumor
Others	Atrophic vaginitis
Pelvic floor relaxation	Iatrogenic obstruction
Anterior vaginal wall prolapse	Anti-incontinence procedures
Apical prolapse	Urethral procedures
Posterior vaginal wall prolapse	
Neoplasm	Miscellaneous
Bladder tumor	Ectopic ureterocele
Urethral tumor	Bladder calculi
Metastatic tumor	Urethral valves

resolution probe can clearly differentiate various intravesical masses such as bladder calculus [5], foreign bodies, intravesical blood clots [7] and hemorrhagic cystitis [8]. These conditions may cause hematuria and can appear simply as an intravesical mass on imaging studies, making them difficult to differentiate from bladder cancer [5,7,8]. Abnormal ultrasonographic changes of the bladder wall are one of the indications for cystoscopic examination. Transvaginal ultrasonographic scanning of the lower urinary tract has been recommended as an initial work-up for women with either gross or microscopic hematuria. For women who have abnormal ultrasonographic findings, cystourethroscopy is suggested, even in the presence of pyuria. However, for women with normal ultrasongraphic findings, medical treatment may be attempted to avoid the discomfort of cystourethroscopy.

In addition to the detection of primary bladder tumors, transvaginal ultrasonography has the promising capability of evaluating the status of bladder infiltration in women with cervical cancers [9]. A system of staging bladder infiltration by cervical cancers has been proposed [9]. Disruption of the endopelvic fascia without involvement of the inner bladder wall is the initial stage of bladder wall invasion (stage I), in which cystoscopy would not reveal any abnormalities of the bladder mucosa. The morphologic changes of the inner bladder wall are proportional to the depth of tumor penetration into the bladder wall. When only the outer one third or half of the inner bladder wall is penetrated (stage II), bladder wall thickness increases but the mucosa remains normal. Thus, cystoscopy still does not reveal the information needed for diagnosis. It is only when the tumor has penetrated further, reaching the inner half of the inner bladder wall (stage III), that abnormalities of the mucosa are visible cystoscopically, i.e. an irregular and elevated bladder mucosa, bullous edema, ncystitis cystica, or telangiectasia. With complete tumor penetration, the inner bladder wall loses its normal architecture and texture and is replaced by invasive tumor cells (stage IV), which are easily detected using cystoscopy [9] (Fig. 1).

VOIDING DYSFUNCTION SECONDARY TO URETHRAL CONDITIONS

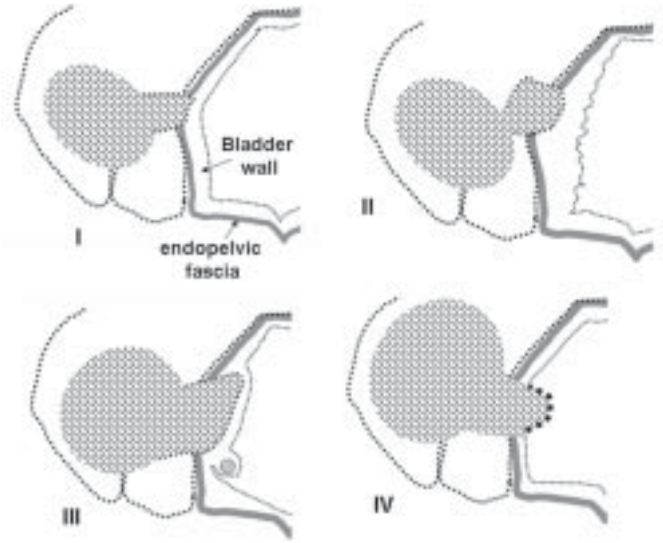

Fig. 1. Illustration of four stages of bladder wall invasion on ultrasound.

Urethral stricture/stenosis

In a series in which the prevalence of the urodynamic outlet obstruction was 6.5%, 13% of cases were secondary to urethral stricture [2]. Urethral stricture or stenosis, which is rare in women, may be congenital or acquired. It may be due to traumatic injury from childbirth, vaginal surgery, or pelvic fracture or it may be secondary to acute or chronic inflammation [10]. Transvaginal ultrasonography may be used to evaluate patients with suggested urethral stricture. On ultrasonography, the normal urethra is shown as a tubular structure with a hypoechoic center representing the urethral mucosa [11]. In cases of urethral stricture, distortion of the anechoic urethral mucosa is clearly demonstrated using ultrasonography. Better delineation of a urethral stricture can be achieved with abdominal pressure on a full bladder, permitting pseudoantegrade filling of the proximal urethra [12]. A hyperechoic structure indicates a fibrotic and nondistensible urethral segment [13], which histologically consists of spongiofibrosis [13, 14]. It is closely related to the ultimate prognosis of urethral stricture [13,14]. Not only for making a diagnosis, ultrasonography also helps visualize the tissue planes during dilation of a stricture [15]. Ultrasonographic visualization ensures penetration and advancement of the dilator exactly through the correct tissue plane and prevents false passage and urethral damage.

Urethral diverticulum

Transvaginal ultrasonography, with its high-resolution visualization of the lower urinary tract, may aid in the diagnosis and treatment of urethral disorders. Using three-dimensional technology, the internal architecture of the paraurethral abnormalities and their spatial relationship to the urethra and bladder, which are important considerations at surgery, are clearly demonstrated on ultrasonography. Complete excision of complex paraurethral anomalies may be performed under transvaginal sonographic monitoring without inadvertent injury to the

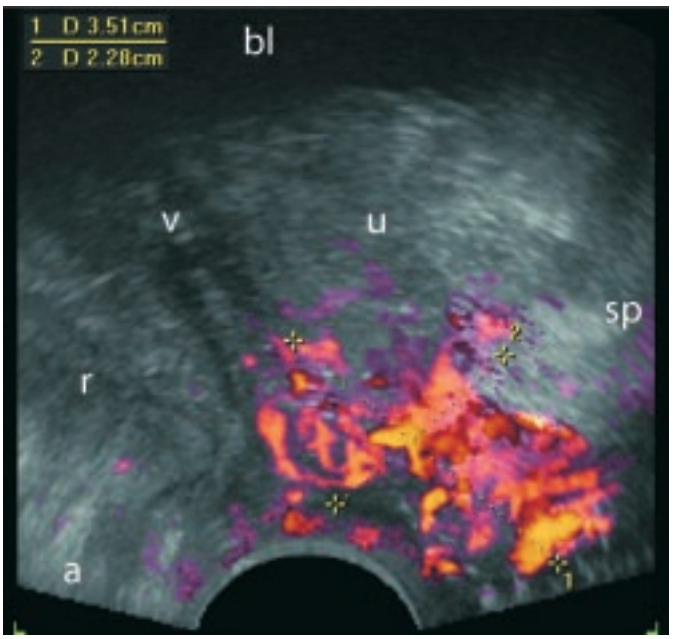

Fig. 2. Power Doppler angiography demonstrating hypervascularity in the distal urethra and vagina (a: anal canal; bl: bladder; r: rectum; sp: pubic symphysis; u: urethra; v: vagina)

bladder or urethra [16]. Transvaginal ultrasonography can make a significant contribution to the management of complex paraurethral abnormalities by supplying pre- and intraoperative information that would otherwise be unavailable. Such information may be important in the prevention of lower urinary tract injury during surgical manipulation of complex paraurethral anomalies [16].

Urethral tumor (primary or metastatic)

In a case of distal urethral obstruction secondary to metastatic paraurethral adenocarcinoma, three-dimensional ultrasonography clearly demonstrated the configuration of the metastatic tumor and its spatial orientation in association with distal urethral obstruction [17]. Three-dimensional ultrasonography at the time the patient had voiding symptoms showed constriction of the echolucent portion of the urethra resulted which from the compressive effect of paraurethral tumor. The symptoms disappeared when the compression was relieved. In addition, based on preoperative imaging information, the tumor was resected as completely as possible with minimal risk of extensive disruption of urethral structure [17].

In a woman with voiding difficulty and acute urinary retention secondary to infiltrating metastatic rectal cancer, transvaginal ultrasonography with three-dimensional scanning and Doppler flow angiography clearly showed obliteration of the distal urethra by an infiltrating tumor [18]. A three-dimensional axial view revealed poorly demarcated echogenic streaks in the normally anechoic portion of the urethra. These imaging results indicated complete occlusion of urethra and were sufficient to indicate the need for a suprapubic cystostomy to relieve the patient's urinary retention [18] (Fig. 2).

Anti-incontinence procedures

Suburethral sling has been becoming the front-line surgery for urodynamic stress incontinence. Ultrasonography provides a clear demonstration of the spatial orientation of the vaginal tape and may help clarify the pathogenesis of voiding dysfunction after a suburethral sling procedure [19]. The synthetic tape appears as an echogenic band underneath the urethra on ultrasonography [19]. Significant voiding dysfunction or complete urinary retention has been reported to complicate 2.8% to 7.6% of TVT procedures [20]. Three-dimensional ultrasonography showed constriction of the echolucent portion of the urethra at the time the patient develops voiding symptoms [19]. With release of the constriction demonstrated on ultrasonography, the symptoms also disappeared [19]. Introital ultrasonography has also been reported to identify intraurethral positioning of the tape as the cause of the patient's symptoms, which was confirmed using urethroscopy [21].

VOIDING DYSFUNCTION SECONDARY TO OBSTETRICAL/ GYNECOLOGIC CONDITIONS

Retroverted gravid uterus

Retroversion of the uterus is present in 15% of pregnancies during the first trimester, but the fundus will usually enter the abdominal cavity with no resulting complications by the end of the first trimester. Impaction of the retroverted gravid uterus occurs in approximately 1 per 3000 pregnancies [22]. Predisposing factors include congenital uterine anomalies, pelvic adhesions, posterior wall leiomyomas, endometriosis, and deep sacral concavity with overhanging sacral promontory [22]. Ultrasonography is able to be used to identify the anteriorly displaced cervix. The bladder is shown to be anteriorly and superiorly displaced in the abdomen. Such a finding on ultrasonography should suggest the possibility of an impacted pelvic mass with urinary retention [22]. Acute urinary retention secondary to a retroverted gravid uterus is caused by a displaced cervix compressing the lower bladder and interfering with drainage to the urethra. The urethra itself is not compressed or distorted. Understanding the pathophysiology of the lower urinary tract may allow maneuvers which prevent acute urinary retention [23].

Gynecologic tumors

When a mass such as an ovarian cyst or a fibroid in the posterior uterine wall crowds the pelvic space, occasionally the mass fails to clear the promontory of the sacrum and becomes impacted in the pelvis. The mass then fills the pelvis, displacing and compressing the lower urinary tract and inciting acute urinary retention [24]. When patients are in the supine position, the impacted pelvic masses displace the cervix superiorly and anteriorly, compressing the lower bladder, leading to obstruction of the internal urethral orifice. During straining, there is no limitation of urethral mobility, but the increased abdominal pressure further compresses the lower bladder. When the subjects stands, the lower bladder fills with urine. There is descent of the bladder neck, and obstruction is relieved. Acute urinary retention in cases of an impacted pelvic mass is caused by a displaced cervix compressing the lower bladder, obstructing the internal urethral orifice. The urethra itself is not compressed or distorted [24]. Transvaginal ultrasonography can then be used to clearly delineate the abnormality. The specific findings in transvaginal ultrasonography include the following: (1) the cervix is displaced superiorly and anteriorly by the impacted mass, compressing the lower bladder and causing it to override the internal urethral orifice; (2) pushing the cervix inward with a vaginal probe relieves the compression and makes clear the distinction between the urethra and bladder; and (3) there is no limitation of urethral mobility during a Valsalva maneuver [24].

CONCLUSIONS

With the recent introduction of high-resolution vaginal probes and three-dimensional techniques, ultrasonography is becoming increasingly useful in pelvic imaging. As yet, ultrasonography has not been investigated as part of the clinical investigating process for female voiding dysfunction. We believe the time has come for such studies to be done. In the meantime, we recommend the use of this diagnostic tool as a means of exploring underlying etiologies and treatment planning for female voiding dysfunction.

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