Clinical Applications of Transrectal Ultrasound in the Prostate and Seminal Tract

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Transrectal ultrasound (US) is the most commonly used imaging tool in the evaluation of the prostate. This article provides a synopsis of the normal and abnormal transrectal US findings of the prostate. The changes in normal transrectal US findings with aging are described, with simplified illustrations. The transrectal US findings of each disease of the prostate are also described. The clues, radiologic or combined with serology, which are helpful for differentiating between common prostatic diseases are also discussed. The seminal tracts are similarly discussed, with an emphasis on male infertility.


KEY WORDS: • prostate • seminal vesicle • ultrasound • utilization

INTRODUCTION

The prostate gland is the site of two common and important diseases in older men: benign prostatic hyperplasia (BPH) and prostate cancer. A revision of prostatic anatomy, serum assays for prostate specific antigen (PSA) and an improvement in imaging techniques have advanced our understanding of prostate disease. Although serum PSA has great sensitivity for detection of prostate cancer, other entities such as inflammation or hyperplasia also result in elevated serum PSA. This lack of specificity of PSA has led to a search for a radiologic study to improve specificity without reducing sensitivity [1–3].

The imaging tools most commonly used are magnetic resonance imaging (MRI) and transrectal ultrasound (US). MRI is superior to transrectal US, and has superior contrast resolution and a larger field of view [4]. Nevertheless, transrectal US has gained widespread acceptance as the initial radiologic examination of patients with abnormal findings on digital rectal examination or increased serum PSA level. The reasons for this are: 1) the transrectal approach, with the use of a high frequency (≥ 9 MHz) probe, allows excellent display of the prostate parenchyma and seminal tract; 2) US can be used easily for biopsy guidance; 3) its availability and cost-efficiency, compared with MRI, makes it the preferred imaging tool; and 4) the concept of a predicted PSA value based on the individual’s prostate volume requires volume estimation, and transrectal US enables an objective and accurate estimation to be made.
For the seminal tracts, transrectal US is also being used as the first-line imaging tool. Transrectal US can demonstrate abnormalities of the seminal tracts responsible for infertility or bloody ejaculation [5], and can also be used to guide a needle for aspiration of dilated seminal tracts and instillation of contrast material to obtain radiographs [6].

This article will provide a synopsis of the anatomy and disease of the prostate and seminal tracts, with emphasis on the clinical applications of transrectal US.

NORMAL PROSTATE AND SEMINAL TRACT ANATOMY

The prostate gland is an exocrine gland with inverted pyramidal shape surrounding the urethra, between the bladder neck and the genitourinary membrane. It is located at the inferior aspect of the bladder neck, and is inferoposteriorly distal to the rectum. The cephalic end is called the base and the caudal end, the apex. The normal prostate is approximately 4 cm in transverse diameter, 3 cm in anteroposterior diameter, 3 cm in craniocaudal diameter, and has a volume of 15 to 20 mL.

According to McNeal’s zonal anatomy [7], the prostate gland is histologically divided into five zones. These consist of the glandular region (including the periurethral glandular tissue zone, transition zone, central zone and peripheral zone), and the non-glandular region (consisting of the anterior fibromuscular stroma) (Fig. 1). The transition zone constitutes about 5% of the prostatic glandular tissue. It is located on both sides of the prostatic urethra and ends at the verumontanum. Most cases of BPH develop in the transition zone [8]. The central zone, located around the base of the prostate in a pyramid shape, makes up approximately 25% of prostatic glandular tissue in the young adult, but constitutes a smaller proportion in elderly men because most of the central zone is compressed by BPH [9]. Seventy percent of prostatic glandular tissue is in the peripheral zone, which is located at the posterior, lateral and apical aspects of the gland. Its ducts drain into the distal urethra, which is distal to the verumontanum [7]. About 70% to 80% of prostate cancers originate in the peripheral zone [8]. The anterior fibromuscular stroma is a non-glandular region lying in front of the prostatic urethra that forms the anterior portion of the prostate gland.

The seminal vesicles are paired, symmetric tubular structures lying just cephalad to the prostate. Their length and width are approximately 3 ± 0.5 cm and 1.5 ± 0.4 cm, respectively. The vas deferens is a continuation of the tail of the epididymis and is located at the superomedial aspect of the seminal vesicles. It dilates to form the ampulla just before it joins the seminal vesicles to form the ejaculatory duct (Fig. 2). The ejaculatory ducts pass obliquely through the prostate to enter the urethra at the

![Fig. 1. McNeal’s zonal anatomy of the prostate.](image)

**Fig. 1.** McNeal’s zonal anatomy of the prostate [7]. Diagrams of the prostate in the midline sagittal (A) and coronal (B) planes show McNeal’s zonal anatomy. **A** = anterior fibromuscular stroma; **T** = transition zone; **C** = central zone; **P** = peripheral zone.

![Fig. 2. Anatomy and transrectal ultrasound findings of the seminal tracts.](image)

**Fig. 2.** Anatomy and transrectal ultrasound findings of the seminal tracts. (A) Diagram of the seminal tracts. **V** = vas deferens; **S** = seminal vesicle; **A** = ampulla. Ultrasound image of the vas deferens (B) and a seminal vesicle (C). This scan, obtained obliquely in the just cranial aspect of the prostate, shows the vas deferens as a thin-walled tubular structure, and a seminal vesicle as a thin-walled hypoechoic structure.
The utricle is the male counterpart of the uterus, which is usually a small dimple on the surface of the verumontanum. In as many as 10% of normal men, the utricle is larger and forms a slit-like aperture lying between the openings of the ejaculatory ducts and extending in a cephalic direction.

**SONOGRAPHIC FINDINGS OF NORMAL PROSTATE AND SEMINAL TRACT ANATOMY**

The anterior fibromuscular stroma and transition zone are usually hypoechoic on US. The echogenicity of the transition zone may become heterogeneous with age (Figs. 3 and 4). The central and peripheral zones are homogeneously isoechoic or hyperechoic and cannot be differentiated from each other on transrectal US [10].

Normal seminal vesicles appear as symmetric, thin-walled, hypoechoic structures and have fine internal echoes. They may appear to be multiculated due to their convolutions. The vas deferens appears as a tubular structure and its walls are thicker than those of the seminal vesicles. Normal ejaculatory ducts can be defined as paired thin echogenic lines coursing through the central zone of the prostate to the verumontanum. The lumina of the ejaculatory ducts are normally not visible on transrectal US.

Transrectal US can determine prostate volume accurately. The most commonly used method to measure prostate volume is the formula for a prolate ellipse, i.e. length x width x height x 0.523 [11,12]. Volumes can then be easily converted to weights because 1 mL of prostatic tissue is equivalent to 1 g of tissue (Fig. 5).

**CONGENITAL ANOMALIES**

**Agenesis**

Failure of developing a mesonephric duct results in agenesis of the ipsilateral kidney, ureter, bladder hemitrigone, seminal vesicle, vas deferens and ejaculatory duct, singly or in combination [13]. Agenesis of a vas deferens is one of the etiologies of male infertility. Transrectal US can demonstrate the absence of a vas deferens and differentiate it from other etiologies such as ejaculatory duct obstruction [14]. Transrectal US helps to guide appropriate clinical and surgical management.

**Midline cysts**

The classification of cysts involving the prostate and seminal tracts is based on their position and embryologic origin. The utricular cyst, muellerian duct cyst, and ejaculatory duct cyst are all located at or near the prostate midline, and therefore, they are collectively called midline cysts. Utricular cysts are intraprostatic, usually smaller than muellerian duct cysts, communicate with the verumontanum, and can be associated with cryptorchidism and hypospadias. Muellerian duct cysts are extraprostatic, do not communicate with the prostatic urethra, and are not associated with genital anomalies. Ejaculatory duct cysts or Wolffian duct cysts are connected with the vas or seminal vesicles (Fig. 6) and thus, may be differentiated from utricular cysts or muellerian duct cysts by the presence of sperm in their content. The differentiation among these cysts is theoretically clear but often difficult on transrectal US [15].
Seminal vesicle cysts

Seminal vesicle cysts are uncommon and usually congenital in origin. At least two thirds of these cysts are associated with ipsilateral renal agenesis because of the common derivation of the seminal vesicles, vas deferens and ureteric bud. Therefore, when a seminal vesicle cyst is detected, evaluation of the ipsilateral kidney is mandatory. Acquired cysts can occur in the seminal vesicles secondary to obstruction or inflammation. A seminal vesicle cyst, whether it is congenital or acquired, appears as a unilocular cystic structure posterolateral to the bladder [16].

**INFLAMMATION**

**Acute prostatitis**

Acute prostatitis presents with symptoms suggestive of acute inflammation (fever and perineal pain or tenderness) and irritative voiding symptoms (urgency, frequency or nocturia). Transrectal US shows diffuse prostate enlargement with homogeneous low-level echogenicity due to edema. A generalized increase in blood flow is also demonstrated on color and power Doppler US. By placing the transducer into the rectum close to the prostate, tenderness may be induced. Although acute prostatitis has the sonographic findings mentioned above, what is more important is clinical correlation with the sonographic findings. Acute prostatitis, caused by bacteria, is generally well controlled by antibiotic treatment, but in some cases, may progress to abscess formation. On transrectal US, the abscess appears as a discrete low echoic or anechoic mass with increased flow signals around it (Fig. 7). Transrectal US-guided aspiration or drainage may be helpful in the treatment of a prostate abscess [17].
**Chronic prostatitis**

Chronic prostatitis is an indolent disease manifesting with relapses of dysuria, urgency and mild perineal pain. The etiology of chronic prostatitis can be bacterial, tuberculous or fungal. In prostatosis (prostatodynia), no pathologic lesion may be found [18]. Transrectal US may demonstrate varying areas of altered echogenicity in the prostate in chronic prostatitis. These include ill-defined heterogeneous low echoic lesions, focal low echoic nodules with or without well-defined borders and a hypoechoic rim in the peripheral zone. Focal or diffuse low echoic lesions in the peripheral zone cannot be differentiated from those of prostate cancers [19]. Transrectal US often shows a thin, hypoechoic rim along the outermost periphery of the prostate (Fig. 8). This hypoechoic rim represents an area spared of inflammatory cell infiltration on histopathologic examination. The presence of a peripheral hypoechoic rim in the prostate may be helpful in the diagnosis of chronic prostatitis [20]. Although chronic prostatitis causes a variety of sonographic findings, those findings are not specific for the diagnosis of chronic prostatitis. Thus, diagnosis needs to rely primarily on clinical conditions.

**Malacoplakia**

Malacoplakia is an uncommon granulomatous inflammation that most commonly affects the bladder, followed by the kidneys, ureters, testes and prostate. Histologically, malacoplakia is characterized by the presence of distinctive histiocytes that contain Michaelis-Gutmann bodies. The etiology is regarded as an incomplete phagocytic function, where histiocytes fail to completely phagocytize bacteria. On transrectal US, malacoplakia may appear as a
hypoechoic lesion (Fig. 9) indistinguishable from prostate cancer [21].

**Seminal vesiculitis**

Seminal vesiculitis is usually found in association with inflammation of the prostate. Imaging findings are nonspecific, including thickened seminal vesicle walls, increased internal echogenicity, cystic dilatation and irregularity of the vesicle lumen (Fig. 10). The seminal vesicle is usually enlarged in acute inflammation, but is shrunken in the chronic inflammatory stage. Calcification may occur with end-stage disease, especially in cases of tuberculosis [22]. Seminal vesiculitis may be the cause of male infertility in patients with low ejaculatory volumes. Transrectal US can easily differentiate low ejaculatory volume secondary to impaired seminal vesicle secretion from that of enlarged seminal vesicles due to ejaculatory duct obstruction [23].

**Benign Prostatic Hyperplasia**

BPH is a disease of the glandular tissues surrounding the prostatic urethra. Approximately 95% of cases of BPH arise in the transition zone, while 5% arise from the periurethral glandular tissue. In most cases, prostate enlargement is present, but not always. Presenting symptoms and signs usually result from obstruction of the prostatic urethra. Once BPH begins to develop in the senescent prostate due to aging, an increase in the volume of the transitional zone and periurethral glandular tissue results [9]. BPH develops in most elderly men, and therefore, the transition zone is more distinct and enlarged sonographically in elderly than in young men.

In BPH, the transition zone and periurethral glandular tissue appears coarser and less echogenic than the peripheral zone. As BPH progresses, the prostate parenchyma between the transition zone and the peripheral gland is compressed to only a few millimeters in thickness [19]. This compressed parenchyma, called a surgical capsule, may be seen as a hypoechoic halo on transrectal US (Fig. 11). Occasionally, BPH can manifest as single or multiple focal nodules. These nodules vary in echogenicity, but are more commonly hypoechoic [24]. Even though the location of these nodules may give some

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**Fig. 8.** Chronic prostatitis in a 47-year-old man. Transrectal US of the prostate in the axial plane shows heterogeneously-increased echogenicity of the prostate and a hypoechoic rim (arrowheads) in the periphery of the prostate.

**Fig. 9.** Malacoplakia of the prostate in a 57-year-old man. (A) Transrectal US in the axial plane shows a well-defined hypoechoic nodule in the posterolateral aspect of the right peripheral zone (arrows). (B) Color Doppler US shows flow signals within the lesion (arrows). US-guided biopsy revealed prostatic malacoplakia.
clues to their identity [25], it is impossible to differentiate these nodules from prostate cancer.

Other sonographic findings include marginal calcification and cystic change. Marginal calcification is commonly seen along the surgical capsule, and the cystic change, developed by glandular duct obstruction, is commonly seen in the transition zone [26].

**TUMORS**

**Prostate adenocarcinoma**

Prostate adenocarcinoma is the most common male malignancy in the USA. Although the incidence of prostate cancer in Korea is not as high as that in the USA, it is increasing due to changes in dietary habits, increasing average male life span and advances in diagnostic techniques.

The typical appearance of prostate cancer is a hypoechoic lesion located in the peripheral zone of the prostate (Fig. 12). In about 60% of prostate cancers, this typical appearance is shown on transrectal US, but is not pathognomonic for prostate cancer. Hypoechoic lesions in the peripheral zone are also seen with other entities, including chronic prostatitis and BPH nodules; thus, the positive predictive value of hypoechoic lesions in the peripheral zone for prostate cancer is unsatisfactory. Several methods can be used to increase the positive predictive value of diagnostic tests for prostate cancer. Using a combination of results from transrectal US and serum PSA, approximately 20% of sonographically negative cancers can be detected [27]. PSA density and velocity can also be used similarly [28]. One third of prostate cancers are isoechoic and, therefore, difficult to demonstrate using transrectal US.

Doppler examination may also have a role in the detection of isoechoic lesions (Fig. 13), but there is a decrease in specificity because of the increased flow signals observed in prostatitis [29]. In a minority of cases, prostate cancer can be hyperechoic because the cancer engulfs benign calcification as it grows, or is associated with dystrophic calcification. Most prostate cancers (80–90%) occur in the peripheral zone, but about 10% originate in the transition zone. It is impossible to diagnose prostate cancer arising in the transition zone by transrectal US because this zone is variable in echogenicity as a result of coexisting BPH.

Although transrectal US is limited in the detection of isoechoic prostate cancer and transitional zone cancer, it remains the most important tool for initial radiologic examination of patients with abnormal findings on digital rectal examination and in patients with increased serum PSA levels. Most importantly, transrectal US can be used to guide prostate biopsies. Systematic biopsy of the prostate using transrectal US guidance is currently the standard procedure for excluding prostate cancer in patients with elevated serum PSA or an abnormal digital rectal exam.
Therefore, transrectal US is the most commonly used imaging tool in urologic practice.

Other malignant neoplasms
Unusual tumors arising in the prostate account for less than 5% of all prostatic malignancies. These tumors, whether variants of adenocarcinoma or non-epithelial tumors, have no specific finding to differentiate them from typical adenocarcinoma (Fig. 14). Only sarcomas tend to be more aggressive than other prostate tumors at the time of diagnosis. In rhabdomyosarcoma (the most common prostatic tumor in pediatric patients), the patient’s age can give a clue as to the differential diagnosis. Most unusual prostate tumors are not associated with significant increases in serum PSA, unlike typical adenocarcinoma [30]. The natural history and response to therapy may differ markedly with typical adenocarcinoma; therefore, tissue diagnosis is required in all cases.

Miscellaneous Conditions

Ejaculatory duct obstruction
Ejaculatory duct obstruction (EDO) can cause male infertility. The recognition of EDO as an etiology of male infertility is important because it is potentially curable with endoscopic surgery. Two-thirds of EDO is congenital, and the remainder results from chronic inflammation or trauma. Not only can transrectal US reveal EDO, but it can also differentiate EDO from other etiologies causing low ejaculatory volume (such as utricular cyst, muellerian duct cyst or seminal vesiculitis).

Hematospermia
Hematospermia is a common clinical problem in urologic practice. The most common cause of hematospermia is inflammation of the prostate and seminal tract, but 5% to 10% of hematospermia is caused by prostate cancer. Therefore, it is necessary to perform transrectal US, given the possibility of prostate cancer – especially in men over 40 years of age.

Seminal vesicle stones
Seminal vesicle stones are usually radiopaque on plain radiographs and, if the stone is large enough, show typical acoustic shadowing. Seminal vesicle stones should not be confused with seminal wall...
calcification that can be found in diabetes, tuberculosis, schistosomiasis, chronic renal failure and advanced age.

REFERENCES