Transrectal ultrasonography in the detection and staging of prostate cancer

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Summary. Transrectal ultrasonography of the prostate has proven to be useful in assisting in the local staging of patients with prostatic carcinoma in following patients after radiation therapy, radical prostatectomy and administration of endocrine therapy and in assisting in prostatic biopsy. The role of prostate ultrasonography for screening and early detection of prostate cancer remains controversial. Significant false positive and false negative studies occur and the natural history of small localized tumors that are not clinically evident remains unknown. Further studies are required to assess the role of this new imaging modality for screening purposes.

Medical ultrasonography developed as an outgrowth of sonar used in World War II; by 1952, ultrasonic technology had advanced to a point where researchers could detect differences between normal and malignant tissue [42, 43]. Transrectal studies were attempted shortly after this time but provided poor-quality images that were difficult to interpret. Working in Japan in 1968, Watanabe and associates [37, 38] used B-mode transrectal ultrasonography with a specially prepared concave transducer to visualize the prostate, and in 1973 King and associates [13] reported their experiences using similar equipment in the United States. Further studies documenting the applications of this technique continued during the 1970s and early 1980s and included such advances as gray-scale instrumentation, higher-frequency transducers, and real-time imaging. Investigators have also used transabdominal and transurethral ultrasonography to visualize the prostate, but transrectal imaging was found to be superior to these modalities in providing the most consistent and reproducible images [10, 11].

The instrumentation presently in use for transrectal ultrasonography of the prostate consists of radial scanners that move in a longitudinal and rotational direction, providing transverse or cross-sectional views of the prostate, linear array scanners that provide a sagittal view of the prostate, and mechanical or phased-array sector scanners that provide views of the prostate in either plane [27, 31, 34]. The ultrasonic beam is produced at variable angles in relationship to the probe, and movement of the probe and transducer provides an infinite number of sections of the prostate and seminal vesicles. Transducers currently in use with a frequency of approximately 7.0 MHz have provided improved resolution of these structures.

On radial transrectal ultrasonography the normal prostate appears as a symmetrical ellipsoid structure lying between the rectal wall and pubic symphysis. It is surrounded by a well-visualized capsule, which is also symmetrical and usually free of distortion. Distension of the rectal wall from the inflated balloon causes posterior portion of the prostate to appear concave. The apex, midsection, and base of the gland can be delineated by moving the probe in a cephalad-caudad direction. Internally, the parenchyma is viewed as multiple, fine homogeneous echoes much weaker than those of the capsule or bony structures. The seminal vesicles, symmetrically paired structures that may vary somewhat in shape, are easily seen in the area of the bladder neck. On linear array scans, the normal prostate is viewed as a round or oval structure in the midline and is otherwise similar in appearance to that observed on radial scanning. In the sagittal view the bladder neck and apical structures can be more clearly seen; this plane of imaging is also beneficial in perineal prostate biopsy.

Ultrasonic characteristics of prostatic carcinoma vary, depending on the instrumentation used. Studies using equipment obtained prior to 1980 demonstrated that carcinomas appear as echo-dense areas [13, 25, 26, 37, 38]. However, with the advent of newer instrumentation and higher-frequency transducers, some investigators have reported that prostatic carcinomas only appear as hypoechoic areas, whereas others have shown that these tumors can be hyperechoic, hypoechoic, isoechoic, or of mixed echogenicity [6, 15, 16, 29].

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Review of these varied experiences suggests that early carcinomas tend to be of lower echogenicity, whereas larger tumors are either of mixed or increased echogenicity due to the development of increased tissue interfaces as the tumor grows and invades other areas of the prostate. Also important to the discussion of tumor characteristics is the observation that patients with confirmed prostatic carcinomas can have normal ultrasonic prostate examinations; this situation has been observed in patients undergoing simple prostatectomy for presumed benign disease who were found to have stage A2 or diffuse carcinoma on histologic examination of the removed tissue. Moreover, not all palpable malignancies can be visualized with this technique [23]; tumors that cannot be visualized have been classified as being isoechoic. Interestingly, recent studies by McNeal and associates [20] have revealed that stage A carcinomas are often located anteromedially. Even when these carcinomas become large, they tend not to spread close to the rectal surface. Experience has shown that transrectal ultrasonography frequently cannot accurately image the anterior portion of the prostate; this limitation may interfere and impair the ability of this procedure to detect tumors in these locations. Not all peripheral hypoechoic areas represent carcinomas: a recent report in which these areas were biopsied indicated that only 21 represented malignant disease [28].

**Staging**

Transrectal ultrasonography of the prostate has proven to be useful in assisting in the local staging of patients with prostatic carcinoma. The finding of a distorted or disrupted capsule in association with an adjacent tumor is a reliable indication of tumor invasion of the prostatic capsule. Seminal vesicles that have been invaded appear distorted or obliterated; the finding of seminal vesicle asymmetry is often associated with invasive disease. Not surprisingly, microscopic invasion of the capsule or seminal vesicles cannot be reliably delineated with this technique [7, 22, 30].

Using transrectal ultrasonography, Pontes and associates [22] evaluated 31 patients with clinically localized prostatic carcinoma prior to radical prostatectomy. Comparisons of the ultrasonic scan with the pathological surgical specimen revealed that transrectal ultrasonography has a sensitivity of 89% and 100% in detecting capsular and seminal vesicle involvement, respectively. The specificity was only 50%, which was attributed to the inability of this technique to detect microscopic disease. The investigators concluded that this modality is valuable in the preoperative evaluation of patients with clinically localized prostatic carcinoma.

More recently, Salo and associates [30] compared computerized axial tomography (CAT) and transrectal ultrasonography in the staging of 38 patients prior to radical retropubic prostatectomy. They found that transrectal ultrasonography demonstrated local extension beyond the capsule with 86% sensitivity and 94% specificity. Overall, the addition of transrectal ultrasonography to the clinical examination increased sensitivity in the detection of extraprostatic involvement from 15% to 92%, whereas the addition of CAT scanning to clinical evaluation increased sensitivity from 15% to only 46%.

A recent report by Shinohara and associates [33] identified the most reliable parameters for detecting seminal vesicle invasion: a low echogenic focus of tumor at the base of the prostate near the seminal vesicle, and loss of the highly echogenic fat plane between the prostate and seminal vesicle (the latter finding they termed the adhesion sign). Of 30 patients with a hypoechoic area at the base, 21 (70%) had pathological seminal vesicle invasion; this finding was highly accurate (85%), with a high positive (70%) and negative predictive value (93%).

When a hyperechoic area at the base was associated with an adhesion sign, 91% of patients had seminal vesicle invasion. Although further investigations are required, it appears that transrectal prostatic ultrasonography is the most specific of the currently available imaging modalities for detecting locally invasive prostatic carcinoma.

**Screening**

Unfortunately, many reports in the literature do not use appropriate statistical terms when specific imaging studies are presented; this has recently been emphasized in a report describing magnetic resonance imaging studies reported in the literature over the past several years [5]. In discussing screening studies, it is important to have an understanding of the statistical terms used, such as specificity, sensitivity, and positive and negative predictive value. The effectiveness of a diagnostic study is often reported in terms of false positive and false negative rates, but more valid terms (see below) should be used more uniformly. Sensitivity can be mathematically expressed as:

\[
\frac{\text{Number of patients with true positive study}}{\text{Number of patients with positive histology}} \times 100.
\]

The term refers to the number of patients who actually have the disease and test positive, divided by the total number of patients with the disease. Specificity can be mathematically expressed as:

\[
\frac{\text{Number of patients with true negative study}}{\text{Number of patients with negative histology}} \times 100.
\]

This term refers to the number of patients who actually do not have the disease and test negative, divided by the total number of patients without the disease.

In assessing studies for the purpose of detecting a disease in a particular population, the valid statistical terms to use are the positive predictive value and the negative predictive value. Such tests are based on the sensitivity,