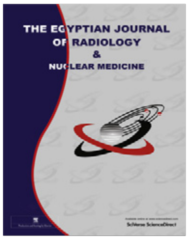
The Egyptian Journal of Radiology and Nuclear Medicine (2012) 43, 465–471

Egyptian Society of Radiology and Nuclear Medicine
The Egyptian Journal of Radiology and Nuclear Medicine
www.elsevier.com/locate/ejrnm
www.sciencedirect.com



ORIGINAL ARTICLE

The role of three dimensional transrectal ultrasonography (3-D TRUS) and power Doppler sonography in prostatic lesions evaluation

Ashraf Talaat Youssef [a,*], Khaled Mohy Elden [b]

[a] *Department of Radiology, Faculty of Medicine, Fayoum University, Egypt*
[b] *Department of Urology, Faculty of Medicine, Fayoum University, Egypt*

Received 10 January 2012; accepted 13 May 2012
Available online 15 June 2012

KEYWORDS
Three dimensional;
Ultrasound;
Prostate;
Power Doppler

Abstract *Aim of work:* To evaluate the role of three dimensional (3D), two dimensional (2D) as well as power Doppler transrectal ultrasound (TRUS) in diagnosis of different prostatic lesions.
Patients and methods: 2-D TRUS, power Doppler and Transrectal 3-D US were performed for 100 patients between April 2009 and April 2010. All patients had been examined clinically with digital rectal examination (DRE) and had serum prostatic specific antigen (PSA) level (total and free). Patient age ranges from 42 to 67 years and the mean age was 55 years. TRUS guided biopsies were done for 77 cases showing any of the followings: abnormal focal lesion with ultrasound, abnormal vascularity with power Doppler exam, abnormal DRE, elevated serum total PSA >4 ng/ml or when the percent-free PSA is 10% or less in an outpatient setting. The results were recorded and analyzed.
Results: 3-D TRUS was more sensitive, specific and more accurate than 2-D TRUS in detecting prostate cancer as it showed estimated sensitivity 78.9% and specificity 94.8% with total accuracy 90.9% with respect to an estimated sensitivity 63.1%, specificity 86.2% and total accuracy 80.5% with 2-D TRUS and was more accurate than 2-D ultrasound in identifying the capsular breaks with an estimated sensitivity 80% with respect to 40% with 2-D TRUS.
Power Doppler showed 84.2% sensitivity in detecting prostatic cancer and was of 100% sensitivity in detecting prostatitis. 3-D TRUS was more accurate in estimating the volume of adenoma in cases of BPH with an estimated error not more than +6% with respect to an estimated error not more than +18% for 2-D TRUS.

* Corresponding author. Tel.: +20 0846371195, mobile: +20 1001849139.
E-mail address: ashraftalaat1@yahoo.com (A. Talaat Youssef).
Peer review under responsibility of Egyptian Society of Radiology and Nuclear Medicine.

ELSEVIER Production and hosting by Elsevier

 http://dx.doi.org/10.1016/j.ejrnm.2012.05.003

Conclusion: 3-D transrectal ultrasound and power Doppler sonography have specific diagnostic capabilities which added significantly to the ultrasound in detecting and staging of prostatic cancer and in the planning for management .They proved highly valuable in the diagnosis of prostatitis and 3-D TRUS was more accurate than 2-D TRUS in estimating the volume of adenomas in patients with BPH.

1. Introduction

Watanabe et al. first introduced TRUS as a clinical investigation for prostate evaluation, since that date and with advancement of ultrasound technology TRUS, became the standard imaging modality for prostatic diseases (1,2). The advances in ultrasound technology machines, particularly the progress in the high frequency transducers, advancement in computer technology and Doppler techniques, made TRUS more reliable for prostate cancers detection (3).

Prostate cancer does not have a uniform appearance on the ordinary two dimension 2-D gray scale images, as malignancies located in the outer (peripheral and central zones) or inner (transition zone) gland have different histologic and biologic appearances so this will be reflected differently on US images (4).

Three dimensional 3-D TRUS demonstrate the anatomic delineation of the prostate and lesions within it and demarcate the structures around the prostate, in three planes simultaneously, the sagittal plane, horizontal (or axial) plane, as well the coronal plane. This enables the physician to reproduce a high resolution image of three dimensions on the US monitor or personal computer in few seconds (3,5).

3-D TRUS allows better assessment of prostate size and its internal zones improve the biopsy yield during transrectal biopsy and increase the sensitivity and specificity for prostate cancer detection over the traditional 2-D gray scale ultrasound. Also it measures accurately the tumor size thus helps in the plane of treatment and the follow up, this improves the outcome and reduces the side effects (6–9).

Color Doppler sonography increases the sensitivity of ultrasound in the detection of prostatic cancer by increasing the positive predictive value from 53% to 77% and in other series it became 80.6% however the presence of inflammation can increase the false positive rate because of associated hyperemia (3,10). The combination of power Doppler with 3-D TRUS increases the rate of cancer detection with optimization of biopsy cores as it helps in targeting areas presenting with abnormal blood flow. Also it helps in detection of extracapsular infiltration by detecting perforating vessels in the capsule with overall accuracy of 92% (11).

2. Aim of work

To evaluate the role of three dimensional (3D), two dimensional (2D) as well as power Doppler transrectal ultrasound (TRUS) in diagnosis of different prostatic lesions.

3. Patients and methods

2-D TRUS, power Doppler sonography and 3D TRUS were performed for 100 patients between April 2009 and April 2010. All patients were referred from urology department and were complaining of lower urinary tract obstructive or irritative symptoms and underwent history taken with international prostatic symptoms score (IPSS) sheet and or they had abnormal digital rectal examination (DRE) and or they had elevated serum prostatic specific antigen (PSA) level. Patient age ranges from 42 to 67 years and the mean age was 55 years.

The patient was examined in left lateral decubitus knee-chest position (11), using 3-D mechanical high frequency transrectal volume probe, GE logiq 7 ultrasonic machine (Milwaukee, WI, USA).

The volume estimation of prostate with 2-D transrectal ultrasonography was done by an ellipsoidal volume calculation. The prostate is considered ellipsoidal in shape and the volume (mL) is $0.523 \times$ width (cm) $\times$ height (cm) $\times$ length (cm), (the widths and heights were measured on axial planes and craniocaudal length on sagittal plane at their greatest diameter), while with 3D we use the 2 plane contour method (2,6).

Consequently the entire gland and its periprostatic tissues (especially fat planes in apical region, and middle lobe in large glands) were examined from apex to base including the seminal vesicles. Gray scale sagittal scanning was then performed from left to right. Every abnormality imaged in both axial and sagittal planes (12,13).

Power Doppler interrogation was performed in the axial plane from apex to base. The color window must cover the entire gland. Finally, biopsies were performed for 77 cases showing suspicious areas within the prostate during 2-D,3-D TRUS, abnormal flow pattern with power Doppler sonography and for cases with abnormal DRE or elevated serum total PSA > 4 ng/ml or when the percent-free PSA is 10% or less after taking patient consent. The patients were instructed to take antibiotics before and after the procedure, to stop any anticoagulants or non steroidal anti-inflammatory drugs and to do an enema before the procedure. Eight tissue samples were taken from different prostatic regions (6 tissue samples were taken from the midlobe parasagittal planes bilaterally at the base, middle and apical prostatic zones and 2 samples from the lateral aspect of each lobe) in addition tissue samples were taken from the suspicious focal lesions or from the seminal vesicles suspected tumor infilteration observed during transrectal ultrasound. TRUS and TRUS guided biopsy were performed in an outpatient setting.

We started the examination by 2D transrectal ultrasound followed by power Doppler ultrasonography to the region of interest to evaluate the presence of hyperemia and there after the 3D ultrasound was activated and the region of interest was scanned with subsequent multiplanar image analysis and surface rendering. 2-D TRUS, power Doppler and 3-D TRUS exams were done by blind operator to the data received from the DRE and PSA serum level.

All data were recorded and analyzed and the final diagnosis was reached from the pathological reports of guided biopsies and from the postoperative final pathological analysis after radical prostatectomy. Estimation of adenomata volume with 2-D and 3-D TRUS was compared with the estimated adenoma volume after transurethral resection of prostate or open prostatectomy in cases with BPH. An estimated% error in volume calculation of adenoma using 2-D and 3-D TRUS was calculated by dividing the difference between the estimated 2-D or 3-D ultrasound volume and the estimated postoperative volume of adenoma/postoperative volume of adenoma.

Statistical analysis of data: The collected data were organized, tabulated and statistically analyzed using SPSS software statistical computer package version 15 (SPSS Inc., USA). Chi (X2) square was used as a test of significance of the accuracy of 2D and 3D TRUS in diagnosing prostatic cancer. Significance was adopted at $P < 0.05$.

4. Results

2-D Transrectal US aided with power Doppler and 3-D TRUS were performed for 100 patients, over the period of 1 year, the final diagnosis was reached in 77 patients.

Eighteen patients showed prostatic carcinomas, one patient showed prostatic sarcoma. All proved with biopsy. 38 patients showed benign prostatic hyperplasia (BPH). Twenty patients diagnosed as prostatitis.

In patients with biopsy proved prostatic cancer 3-D TRUS showed estimated sensitivity 78.9% and specificity 94.8% with total accuracy 90.9% (Tables 3 and 4) with respect to an estimated sensitivity 63.1%, specificity 86.2% and total accuracy 80.5% with 2-D TRUS (Tables 1 and 2).

3-D TRUS clearly identifies the extraprostatic spread to the periprostatic fat in 3 patients, infiltration to the seminal vesicles in 3 patients, infiltration to the base of urinary bladder in 2 patients and also the presence of capsular breaks in 4 patients out of 5 proved from the pathological reports after radical prostatectomy confirm that the lesion is totally intra glandular in 6 patients.

The results were equivocal or negative in 3 patients by 2D ultrasonography for detecting intra glandular lesions and were negative in detecting capsular breaks in 3 patients out of 5 proved by biopsy but it was able to detect all patients with infiltration to the periprostatic fat planes and the base of urinary bladder in 2 patients out of 3 with seminal vesicles infiltration (Table 5). Both techniques failed to diagnose 2 patients with biopsy proved transitional zone carcinoma and 2 patients with localized intra glandular peripheral zone lesions, possibly due to the isoechoic nature of the lesions in the later.

In patients with benign prostatic hyperplasia (BPH), the postoperative data after transurethral resection of prostatic

Table 1 Summarizes the results of 2-D TRUS in detecting biopsy proved prostatic cancer.

	Biopsy		Total
	+ve	−ve	
2-D TRUS			
+ve	12 (TP)	8 (FP)	20 (all test positive)
−ve	7 (FN)	50 (TN)	57 (all test negative)
Total	19 (all diseased)	58 (all disease free)	77 (grand total)

TP = true positive.
FP = false positive.
FN = false negative.
TN = true negative.

Table 2 Accuracy of 2-D TRUS in detecting biopsy proved prostatic cancer.

Sensitivity	63.1%
Specificity	86.2%
+ve predictive value	60.0%
−ve predictive value	87.7%
Total accuracy	80.5%

P-value = < 0.0001.
Sensitivity: true positive rate (TPR) = diseased with positive test/all diseased.
Specificity: true negative rate (TNR) = disease free with negative test/all disease free.
False positive rate (FPR): disease free with positive test/all disease free.
Positive predictive value (PPV): diseased with positive test/all with positive test.
Negative predictive value (NPV): disease free with negative test/all with negative test.

Table 3 Summarizes the results of 3-D TRUS in detecting biopsy proved prostatic cancer.

	Biopsy		Total
	+ve	−ve	
3_D TRUS			
+ve	15 (TP)	3 (FP)	18 (all test positive)
−ve	4 (FN)	55 (TN)	59 (all test negative)
Total	19 (all diseased)	58 (all disease free)	77 (grand total)

Table 4 Accuracy of 3-D TRUS in detecting biopsy proved prostatic cancer.

Sensitivity	78.9%
Specificity	94.8%
+ve predictive value	83.3%
−ve predictive value	93.2%
Total accuracy	90.9%

P-value = *< 0.0001.*

Table 5 Comparison between the sensitivity of 2-D TRUS and 3-D TRUS in staging of biopsy proven prostatic cancer.

Lesions	Sensitivity% of 2-D TRUS	Sensitivity% of 3-D TRUS
Capsular breaks	40.0	80.0
Spread to extra prostatic fat	100.0	100.0
Infiltration to urinary bladder	100.0	100.0
Infiltration to seminal vesicles	67.0	100.0
Intra glandular lesions	50.0	100.0

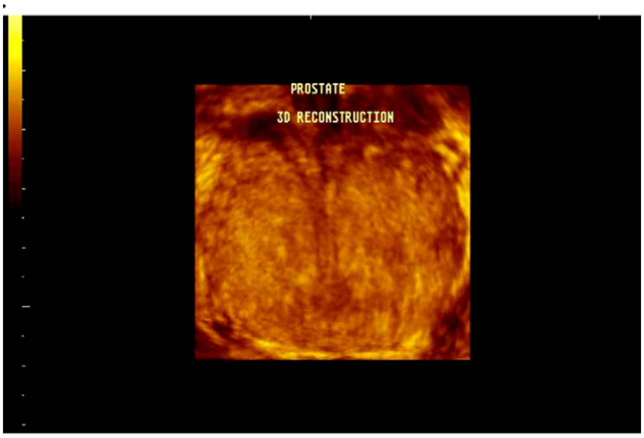


Fig. 1 3-D Transrectal US reconstruction with volume rendering of normal prostate.

adenomas or open prostatectomy received and compared with 2-D and 3-D TRUS results showed that 3-D TRUS was superior to 2-D ultrasonography in calculating the volume of adenomas with an estimated error not more than $\pm 6\%$ with regard to an estimated error not more than $\pm 18\%$ for 2-D TRUS. 3-D ultrasound showed excellent delineation of the transitional zone especially in the coronal plane which is the blind plane for 2-D ultrasonography.

In patients with acute prostatitis the combination of power Doppler US and 2D ultrasonography or 3D ultrasonography gave better results than the use of 2D or 3D TRUS alone. Power Doppler US helped in identifying the hyperaemic prostatic foci and we suggest that the presence of periurethral zone of hyperemia and irregular lucency is the most valuable sign for inflammatory group (seen in all of our 20 patients) as well as the presence of congested periprostatic venous plexus.

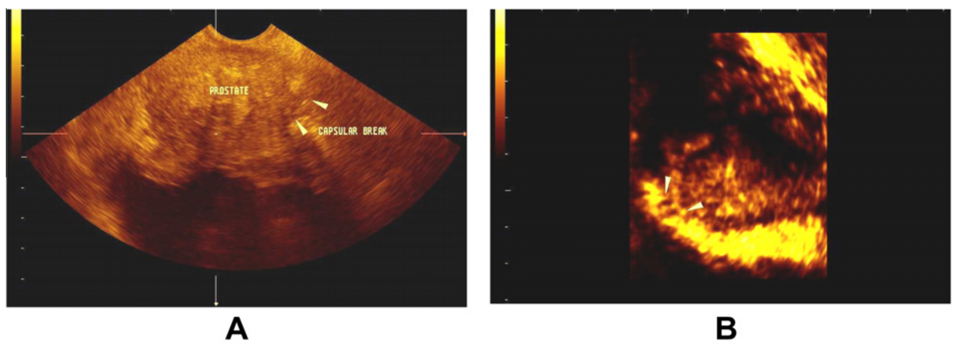


Fig. 2 2-D TRUS (A) and 3-D TRUS (B) images for prostate cancer with focal areas of capsular breaks.

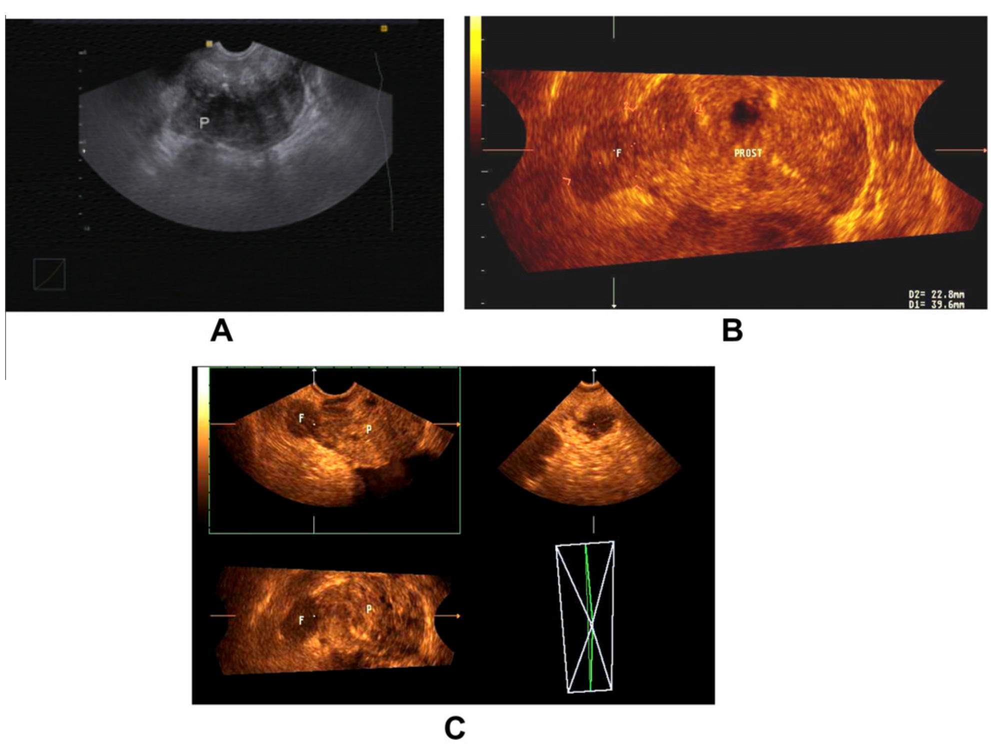


Fig. 3 2-D TRUS (A) coronal reformation (B) 3-D TRUS multiplanar image analysis (C) showing prostate cancer with extension to periprostatic fat planes.

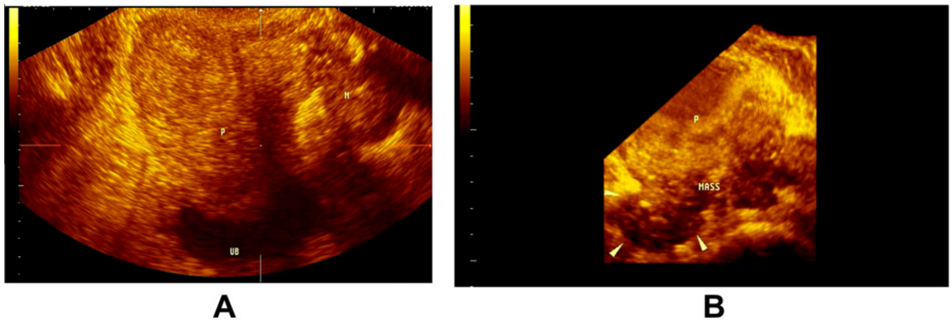


Fig. 4 2-D TRUS (A) and 3-D reconstruction (B) of transitional zone carcinoma with extension to the periprostatic fat planes.

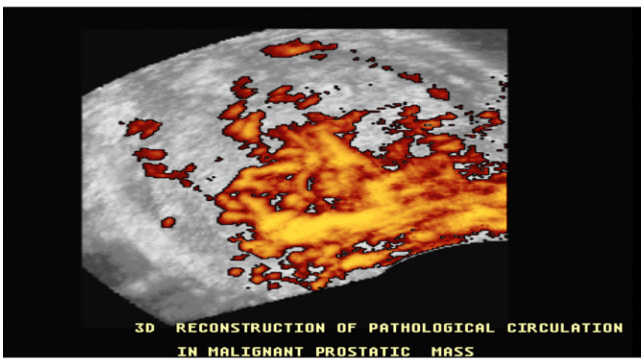


Fig. 5 3-D power Doppler of prostate cancer.

5. Discussion

Benign prostatic hyperplasia mainly involves the inner gland and showed heterogenous echotexture by US. The glandular hyperplasia showed echogenic texture, while stromal hyperplasia appears hypoechoic (14).

3-D TRUS offers high resolution volume rendering image to the prostate (Fig. 1) and is highly valuable in patients with BPH as it offers excellent delineation to the transitional zone by the coronal scan and the accurate volume estimation with an estimated error not more than ±6% with respect to an estimated error not more than ±18% with 2-D TRUS in volume calculation as shown in our study which allows for the optimum decision of management whether surgical (open or endo) or nonsurgical (Figs. 6 and 7). Also with introduction of laser therapy for BPH, it allows for accurate guided placements of laser fibers within the transitional zone which is an advantage cannot be offered by 2D ultrasound (15).

Patients with prostatic cancer areas suspicious of cancer were seen as hypoechoic (in some cases it became isoechoic or hyperechoic) or as glandular asymmetry. Suspicious of extracapsular disease is seen as a disruption of the periprostatic fat layer in association with a hypoechoic lesion; and suspicious of seminal vesicle invasion appears as obliteration of the angle between the seminal vesicle and the base of the prostate, or continuation of the hypoechoic lesion into the seminal vesicles (3,4,7,8).

The traditional 2-D ultrasound uses two-dimensional technique to visualize a three dimension disease process with reported sensitivity in staging the prostatic cancer varying from 50% to 90% (16) and in some series 2-D TRUS adds little advantages over the digital rectal examination.

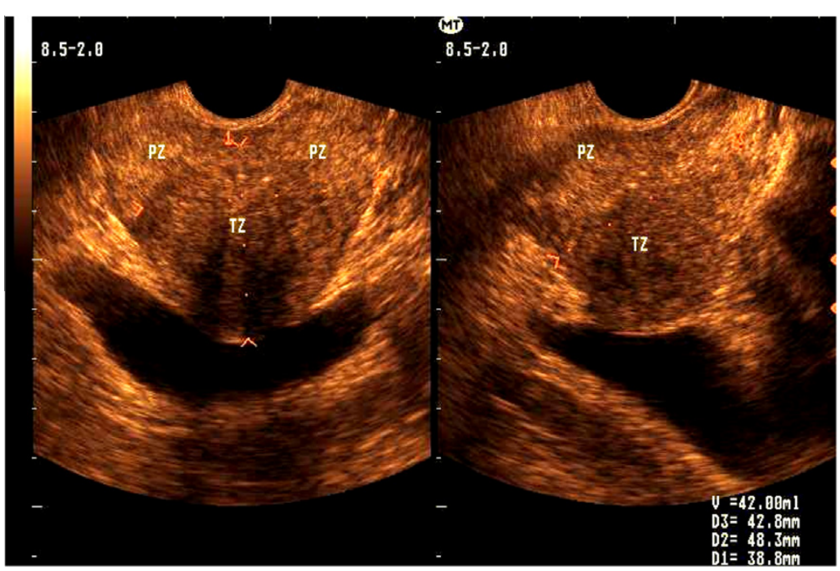


Fig. 6 2-D TRUS study of prostate with BPH showing enlarged transitional zone with intra vesical protrusion.

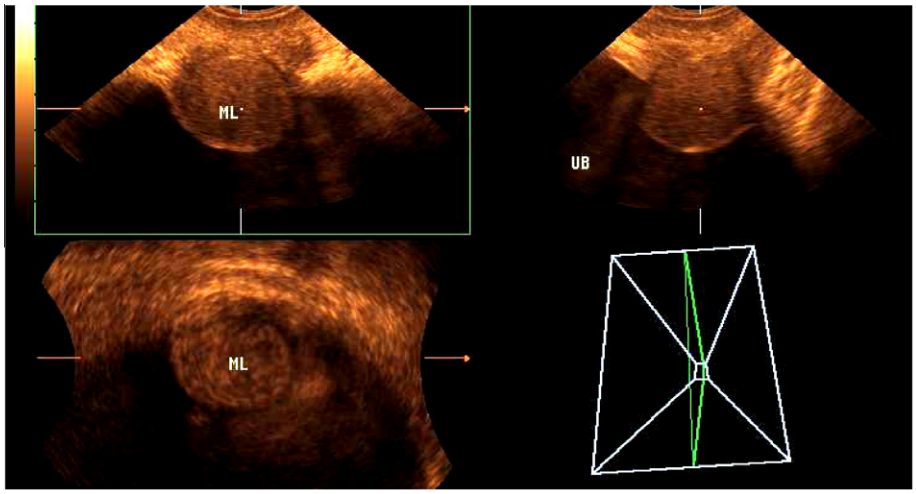


Fig. 7 3-D TRUS multiplanar image analysis showing enlarged middle lobe with intra vesical protrusion in patient with BPH.

Garg et al. (17) reported 94% accuracy of 3D ultrasound in staging prostate cancer with sensitivity of 80% and specificity of 96% in a pilot study. Strasser et al. reported that 3-D TRUS was 87% sensitive and 94% specific for extracapsular extension of prostate cancer (18). In our current study 3-D TRUS was more sensitive, specific and more accurate than 2-D TRUS in detecting prostate cancer as it showed estimated sensitivity 78.9% and specificity 94.8% with total accuracy 90.9% with respect to an estimated sensitivity 63.1%, specificity 86.2% and total accuracy 80.5% with 2-D TRUS and was more accurate than 2-D ultrasound in identifying the capsular breaks (Fig. 2A and B) which is expected due to the much higher image resolution especially in 3-D volume rendering images and the precise delineation of the prostatic zones and the periprostatic structures in multiplanar image analysis. 3-D TRUS was highly sensitive in detecting infiltration to the urinary bladder base, seminal vesicles and periprostatic fat planes (Figs. 3 and 4).It was of less accuracy in identifying the intra prostatic cancer either due to lesions involving the transitional zone or the isoechoic nature of the lesions involving the peripheral zone. However it was more sensitive than 2-D TRUS in identifying the intra glandular lesions.

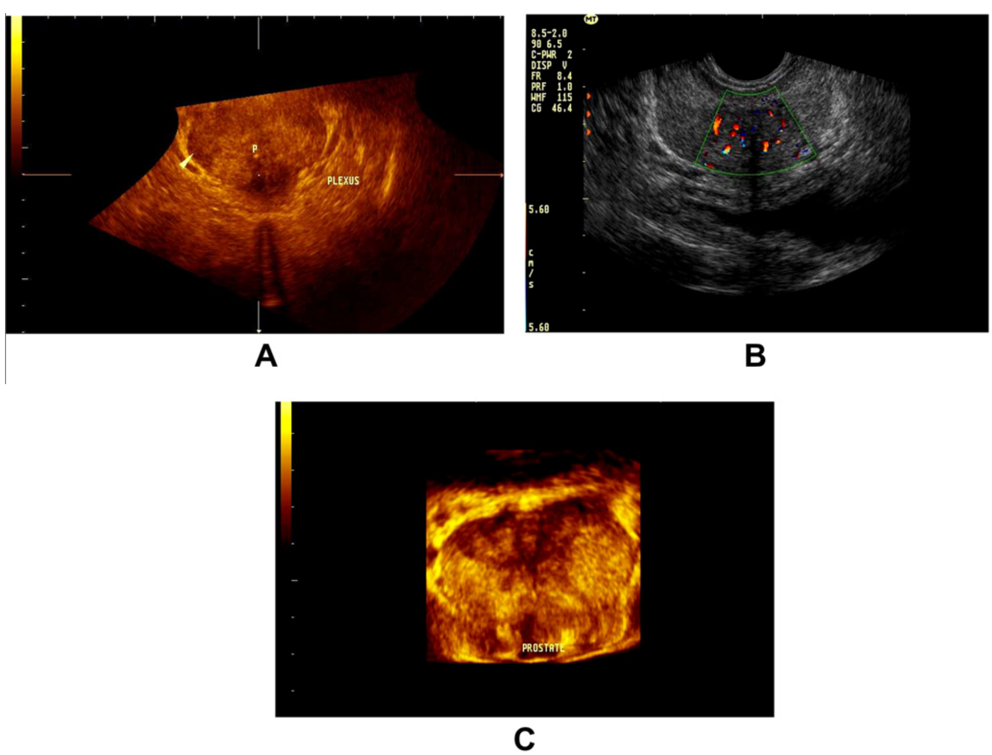


Fig. 8 2D TRUS (A), directional power Doppler study (B) and 3-D reconstruction (C) showing periurethral zone accentuated halo of lucency and hyperemia suggesting of prostatitis.

3D TRUS helps in accurate planning for the therapy as it is more accurate than 2D TRUS in staging the prostate cancer and detection of capsular breaks as the presence of capsular breaks increases the chance for post radical prostatectomy recurrence. Based on its accurate volume calculations 3-D TRUS can also give the volume of malignant lesion which helps in post hormonal therapy follow up. Previous studies showed that 3-D TRUS was of great benefits in guided biopsies as it allows accurate targeting of prostatic lesions. Also the feasibility of 3-D TRUS to assess the probe placement in cryoablation of localized prostatic cancer in patients unsuitable for surgery was well recognized (19).

The introduction of power Doppler aided TRUS added significantly to the diagnosis of prostate cancer, Sauvain et al. investigated 323 men, 282 with suspected cancer, 92.3% of cancers showed abnormal flow and 7.7% showed no measurable flow. If a hypoechoic lesion seen on gray scale US had increased blood flow the risk of positive prostatic biopsy was 81% while the lesion is hypovascular the risk was 14% (20).

In our current study 16 patients out of 19 with biopsy proved prostatic cancer showed abnormal blood flow pattern (Fig. 5) with an estimated sensitivity of power Doppler 84.2%.

For patients with acute prostatitis power Doppler sonography in our current study was 100% sensitive in the detection of the disease and added significantly to the accuracy of 2-D ultrasonography in the diagnosis. The presence of periurethal hyperemia and congested peri prostatic venous plexus were the most helpful criteria in diagnosis (Fig. 8). Venziano et al. reported increased vascularity in cases with prostatitis matched with the severity of symptoms (21).

Our main limitation during the study that we did not have a wide number of patients for each specific prostatic disease as we were dependent only on the patients who attended to our hospital and so we recommend further studies which correlate the image findings with the pathological results in a large number of patients with specific prostatic disease.

6. Conclusion

3-D Transrectal ultrasound and power Doppler sonography have specific diagnostic capabilities which added significantly to the ultrasound in detecting and staging of prostatic cancer and in the planning for management. They proved highly valuable in the diagnosis of prostatitis and 3-D TRUS was more accurate than 2-D TRUS in estimating the volume of adenomas in patients with BPH.

References

(1) Watanabe H, Kaiho H, Tanaka M, Terasawa Yl. Diagnostic application of ultrasonotomography to the prostate. Invest Urol 1971;8:548–59.
(2) Hendrikx Safarik L, Hammerer P. TRUS and biopsy: practical aspects. Eur Urol 2002:41–6.
(3) Mehta S, Azzouzi A, Hamdy FC. Three dimensional ultrasound and prostate cancer. World J Urol 2004;22:339–45.
(4) Lee F, Siders DB, Torp-Pedersen ST, Kirscht JL, McHugh TA, Mitchell AE. Prostate cancer: transrectal ultrasound and pathology comparison. A preliminary study of outer gland (peripheral and central zones) and inner gland (transitional zone) cancer. Cancer Suppl 1991;67:1132–42.
(5) Strasser H, Janetschek G, Reissigl A, Bartsch G. Prostate zones in three dimensional transrectal ultrasound. Urology 1996;47(41).
(6) Sun Ho Kim, Seung Hyup Kim. Correlations between the various methods of estimating prostate volume transabdominal, transrectal, and three-dimensional US. Korean J Radiol 2008;9(2):134–9.
(7) Yuh-Shyan Tsai1, Chia-Horng Chen, Yi-Hsiang Lin, Tzong-Shin Tzai1. Transrectal ultrasound for prostate cancer: perspectives from National Cheng Kung University Hospital. J Med Ultrasound 2007;15:3.
(8) Djavan Bob, Mesut R, Keywan Gh, Michael M. Diagnosis of prostate cancer: the clinical use of transrectal ultrasound and biopsy. EAU Update Series 2003;1:9–15.
(9) Djavan B, Ravery V, Zlotta A, Dobronski P, Dobrovits M, Fakhari M, et al. Prospective evaluation of prostate cancer detected on biopsies 1, 2, 3 and 4: when should we stop? J Urol 2001;166(5):1679–83.
(10) Kelly IMG, Lees WR, Rickards D. Prostate cancer and the role of colour Doppler ultrasonography. Radiology 1993;189:153–6.
(11) Sauvain JL, Palascak P, Bourscheid D, Chabi C, Atassi A, Bremon JM, et al. Value of power Doppler and 3D vascular sonography as a method for diagnosis and staging of prostate cancer. Eur Urol 2003;44:21–31.
(12) Athanasios P, Panagiotis E, Savvas T, Fotios T, Hercules P, Irene N, et al. Curr Probl Diagn Radiol 2005 March/April. Transrectal ultrasonography and ultrasound-guided biopsies of the prostate gland: how, when and where. Curr Probl Diagn Radiol 2005 March/April.
(13) Littrup JP, Bailey ES. Prostate cancer the role of transrectal ultrasound and its impact on cancer detection and management. Radiol Clin North Am 2000;38:87–113.
(14) Sedelaar JPM, Van Roermund JGH, Van Leenders GLJH, Hulsergen-Van Dekaa CA, Wijkstra H, Dela Rosette JJMCH. Three dimensional gray scale ultrasound evaluation of prostate cancer compared with benign prostatic hyperplasia. Urology 2001;57:914–20.
(15) Strasser H, Janetschek G, Horninger W, Bartsh G. Three-dimensional sonographic guidance for interstitial laser therapy in benign prostatic hyperplasia. J Endourol 1995;9:497–501.
(16) liebross RH, Pollack A, Lankford SP, Zagras GK, Von Eschenback AC, Geara FB. Transrectal ultrasound for staging prostate carcinoma prior to radiation therapy. Cancer 1999;85, 1577-1558.
(17) Garg S, Fortling B, Chadwick D, Robinson M, Hamdy FC. Staging of prostate cancer using 3-dimensional trans-rectal ultrasound images a pilot study. J Urol 1999;162:1318–21.
(18) Strasser H, Frauscher F, Klausser A, Helweg G, Barsch G. Three-dimensional transrectal ultrasound in staging of localized prostate cancer. J Urol 2003;169(Suppl. 4):299A.
(19) Chin JL, Downey DB, Mulligan M, Fenster A. Three dimensional transrectal ultrasound guided cryoablation for localised prostate cancer in nonsurgical candidates: a feasibility study and report of early results. J Urol 1998;159:910–4.
(20) Sauvain JL, Palascak P, Bourscheid D, Atassi A, Bremon J, Palascak R. Value of power Doppler and 3-D vascular sonography as a method for diagnosis and staging of prostate cancer. Eur Urol 2003;44:21–31.
(21) Venziano S, Palvica P, Mannini D. Color Doppler ultrasonography scanning in prostatitis: clinical correlation. Eur Urol 1995;.28(1):6–9.