Received:
6 October 2015

Revised:
12 January 2016

Accepted:
8 February 2016

<http://dx.doi.org/10.1259/bjr.20150830>

Cite this article as:

Danish Qaseem SM, Ghonge NP, Aggarwal B, Singhal S. Prospective evaluation of prostate with transrectal spectral Doppler with biopsy correlation: a clinicopathologic study. *Br J Radiol* 2016; **89**: 20150830.

FULL PAPER

Prospective evaluation of prostate with transrectal spectral Doppler with biopsy correlation: a clinicopathologic study

^{1,2}SYED M DANISH QASEEM, DMRD, DNB, ³NITIN P GHONGE, MD, DNB, ⁴BHARAT AGGARWAL, MD, DNB and ⁵SANJEEV SINGHAL, MS

¹Vatika Medicare, Hauz Khas, New Delhi, India

²Mansoor Manzil, Jamia Urdu Road Aligarh, Uttar Pradesh, India

³Apollo Hospital, New Delhi, India

⁴Max Hospital, New Delhi, India

⁵Northern Railway Central Hospital, New Delhi, India

Address correspondence to: Dr Syed M Danish Qaseem

E-mail: danish_qaseem@rediffmail.com

Objectives: To compare the transrectal (TR) spectral Doppler findings between benign prostatic hyperplasia group and prostate cancer group.

Methods: All the patients were assessed for adequate preparation, and informed consent was obtained prior to the procedure. The control group ($n = 33$) comprised patients who were negative for malignancy on biopsy. The study group ($n = 22$) were positive for malignancy and were also divided into three groups on the basis of the Gleason score. Study parameters included mean values for resistive index (RI), pulsatility index (PI), systolic/diastolic ratio (S/D) and peak systolic velocity (PSV). These were separately measured for bilateral capsular and urethral branches and compared between groups. In patients with unilateral tumour, these were compared between the tumour and non-tumour sides. Finally, the parameters were compared with patient's age. Mann-Whitney U test was used to evaluate the statistical significance.

Results: The mean values of RI, PI, S/D and PSV were found to be 0.84/1.03, 1.8/1.99, 3.93/4.45 and 15.52/16.15 cm s^{-1} , respectively, in the control and study groups which were not statistically significant. In patients with unilateral malignancy ($n = 16$), there was no significant difference from the non-tumour side. Doppler parameters showed statistically significant relationships with age. The mean of minimum RI was found to be 0.60 in patients less than 60 years of age and 0.76 in patients more than or equal to 60 years of age in the benign category (p -value = 0.014). The PI and S/D also showed significant difference in the benign category.

Conclusion: TR spectral Doppler parameters did not reveal any significant difference in patients with or without prostatic malignancy, irrespective of the Gleason grade. Doppler parameters, however, showed significant correlation with age and were lower in younger patients.

Advances in knowledge: TR spectral Doppler is unlikely to emerge as a diagnostic and prognostic tool for prostate carcinoma.

INTRODUCTION

The prostate (derived from Greek word “προστάτης”—prostates, meaning: “one who stands before” or “protector”) is a compound tubuloalveolar exocrine gland of the male reproductive system. The common prostatic disorders include benign hyperplasia, prostatitis and cancer. Early diagnosis of prostatic cancer is, however, the most important objective of prostatic imaging. Although, the 5-year survival rate continues to improve, prostate cancer remains a compelling medical health problem. Greyscale transrectal ultrasound (TRUS) is the most commonly used modality for evaluating the prostate. The use of colour Doppler ultrasound (CDUS) as a non-invasive means for displaying the vascular anatomy of the prostate gland

produces a real-time, reproducible and symmetric flow pattern. This study was carried out to compare the transrectal (TR) spectral Doppler findings between the benign and malignant disease processes in the prostate and to assess whether they can help in distinguishing between the two and to evaluate the performance of this radiological parameter in predicting the aggressiveness of malignant tumour of the prostate.

METHODS AND MATERIALS

The study was carried out after obtaining approval from the institutional ethics committee. The present study was carried out over a period of 13 months and included 55 patients. Regarding the inclusion criteria, all patients

who were referred for TR biopsy of the prostate and had serum prostate-specific antigen (PSA) level were included. The prostatic weight estimation on TRUS and TR spectral Doppler analysis was carried out prior to the biopsy procedure (ultrasound machine used was Antares™; Siemens, Erlangen Germany). During the TR Doppler examination, the variables which were assessed included resistive index (RI), pulsatility index (PI), systolic/diastolic ratio (S/D) and peak systolic velocity (PSV, cm s^{-1}). These values were separately measured for each lobe at the right capsular artery (CA) (Figure 1), left CA (Figure 2), right urethral artery (UA) (Figure 3) and left UA (Figure 4).

The values of urethral branches and the capsular branches of the prostate were separately correlated in the control and study groups, and their statistical significance was analysed.

The values of the urethral branches and the capsular branches of the prostate were also compared between the right and left sides and compared with the side of the malignancy on biopsy.

The Doppler evaluation of the prostate was carried out as follows:

The means of the Doppler indices were compared between the benign and malignant groups, between the cancerous and non-cancerous sides in patients who had unilateral malignancy and amongst the benign and Subgroup A, Subgroup B and Subgroup C.

Subsequently, the whole data were divided into groups based on the patient age (whether less than or equal to 60 years or above 60 years) and the serum PSA levels (whether less than or equal to 4 ng ml^{-1} or more). The Doppler indices (mean of minimum of RI, PI, S/D and maximum of PSV) were evaluated for patients less than or equal to 60 years of age and those above 60 years

separately. This was performed separately in benign and malignant category of patients.

The Doppler variables were obtained from the right and left urethral and capsular arteries of the prostate. Three readings were obtained for each artery, and the mean was calculated for each variable. The readings were obtained by a single observer who had an experience of approximately 12 years in TRUS examination.

The needle used for the biopsy procedure was an 18-gauge Core Disposable Core Biopsy Instrument (Bard® Max-Core®) with a penetration depth of 22 mm and length of sample notch being 18 mm. The needle length was 16 cm. "Extended core biopsy" method was used for the procedure. A maximum of 12 samples were taken, with 6 samples from each lobe. Two samples were taken each from the apex, base and mid part of the prostate on one side. In patients with focal lesions, the lesions were included. The extent of tumour involvement was not assessed on biopsy. The number of samples, however, varies depending upon the patient's co-operation with a minimum of at least six samples. The samples were collected in sample bottles containing formalin with separate bottles for the right and left lobes and were sent for histopathological examination. All the patients were instructed to stop aspirin, if they were taking any for at least 10 days prior to the procedure. All the patients were also instructed to stop non-steroidal anti-inflammatory drugs (for at least 5 days) and anticoagulants (for at least 7 days), if they were taking any, and to have their bleeding time, clotting time, prothrombin time and international normalized ratio assessed prior to the procedure. The patients were also advised to take capsule ciprofloxacin 500 mg twice a day for 5 days, starting a day prior to the procedure. Informed consent was obtained from all the patients prior to the procedure. Patients with recent history of

Figure 1. Method of obtaining Doppler indices from the right capsular artery. PI, pulsatility index; PSV, peak systolic velocity; RI, resistive index; S/D, systolic/diastolic ratio.

Figure 2. Method of obtaining Doppler indices from the left capsular artery. PI, pulsatility index; PSV, peak systolic velocity; RI, resistive index; S/D, systolic/diastolic ratio.

TURP, urinary tract infection, abdominal surgery or radiotherapy for prostatic or extraprostatic indications were excluded from the study. The patients were divided into the control and study groups based on the results of the TR prostate biopsy. The total numbers of patients in each group are likely to differ from each other.

Control group

Patients with TR biopsy of prostate diagnosis which is negative for malignancy.

Study group

The study group was further divided into three subgroups on the basis of the Gleason score.

Subgroup A: patients with TR biopsy of prostate diagnosis which is positive for malignancy and had a Gleason score of ≤ 5

Subgroup B: patients with TR biopsy of prostate diagnosis which is positive for malignancy and had a Gleason score of 6–7

Subgroup C: patients with TR biopsy of prostate diagnosis which is positive for malignancy and had a Gleason score of ≥ 8 .

Figure 3. Method of obtaining Doppler indices from the right urethral artery. PI, pulsatility index; PSV, peak systolic velocity; RI, resistive index; S/D, systolic/diastolic ratio.

Figure 4. Method of obtaining Doppler indices from the left urethral artery. PI, pulsatility index; PSV, peak systolic velocity; RI, resistive index; S/D, systolic/diastolic ratio.

Statistical analysis

Parametric tests

Unpaired *t*-test was used to compare the continuous variables between the benign and malignant groups. One-way analysis of variance was followed by Tukey's procedure to do multiple comparisons for the continuous variables across the three groups (benign, Subgroup A and Subgroup B).

Non-parametric tests

Mann-Whitney *U* test was used to compare the distribution of benign and malignant groups for mean RI variable and Kruskal-Wallis test was used to compare benign with Group A and Group B. Wilcoxon signed-rank test was applied to compare variables in cancerous and non-cancerous sides of the same subjects.

χ^2 /Fisher's test was used for categorical variables. A *p*-value <0.05 was considered as significant.

RESULTS

A total of 55 patients were studied out of which 33 turned out to be benign on biopsy, whereas the rest 22 turned out to be malignant on biopsy. On comparing the benign group (control

group) with the malignant group (study group), the mean value and geometric mean were higher for mean PI, mean RI, PSV and S/D in the malignant group than in the benign group, but the variation was not statistically significant.

The mean values of RI, PI, S/D and PSV were found to be 0.84/1.03, 1.8/1.99, 3.93/4.45 and 15.52/16.15 cm s^{-1} , respectively, in the control and study groups (Table 1).

Furthermore, the patients who were positive for malignancy on biopsy were evaluated, and the Doppler indices were compared on the cancerous side with that of the non-cancerous side in patients who had unilateral malignancy.

There were 16 subjects who had unilateral cancer, whereas 6 subjects had bilateral cancer, and we excluded the bilateral subjects and compared the Doppler indices on the cancerous side *vs* non cancerous side in unilateral subjects. Wilcoxon signed-rank test was used to compare cancerous side with non-cancerous side for average of RI, PI, S/D and PSV in UA and CA on either side. The difference in the S/D variable was found to be statistically significant ($p = 0.026$) between the cancerous and non-cancerous sides, and the mean (median) value was higher

Table 1. Comparison of Doppler indices between benign group (control group) and malignant group (study group)

Variable	Benign group (<i>n</i> = 33)			Malignant group (<i>n</i> = 22)			<i>p</i> -value	Significance
	Mean	SD	Geometric mean	Mean	SD	Geometric mean		
PI	1.8	0.72	1.69	1.99	1.14	1.78	0.615	NS
RI	0.84	0.18		1.03	0.70		0.594	NS
PSV	15.52	4.50		16.15	4.42		0.608	NS
S/D	3.93	0.99		4.45	1.47		0.122	NS

NS, not significant; PI, pulsatility index; PSV, peak systolic velocity; RI, resistive index; S/D, systolic/diastolic ratio; SD, standard deviation.

in the cancerous side (5.01) than in the non-cancerous side (4.15). The RI and PSV were also higher on the cancerous side, whereas the PI was higher on the non-cancerous side. However, none of these differences were clinically significant.

Finally, the various study parameters were studied amongst the benign group and the three subgroups which were formed from the malignant group. Three subgroups were formed from the malignant subjects based on their Gleason scores—Subgroup A (Gleason score ≤ 5); Subgroup B (Gleason score between 6 and 7); Subgroup C (Gleason score ≥ 8). Since Subgroup C had only a single case, we excluded this subject from the analysis when the benign group was compared with Subgroup A and Subgroup B.

None of the Doppler parameters varied significantly amongst the groups. The mean values of RI, PI, S/D and PSV were found to be 0.84/1.15/0.94, 1.8/2.15/1.77, 3.93/4.78/4.22 and 15.52/15.26/17.12 cm s^{-1} respectively in control group, Subgroup A and Subgroup B.

The whole data were also analysed dividing it into groups based on the age (whether less than or equal to 60 years or above 60 years). The Doppler indices (mean of minimum of RI, PI, S/D and maximum of PSV) were evaluated for patients less than or equal to 60 years of age and for those above 60 years separately. This was performed separately in benign and malignant category of patients.

The Doppler parameters showed significant correlation with age and were lower in younger patients and thus led to the conclusion that age-related benign prostatic hyperplasia (BPH) changes can affect the blood flow, thereby affecting the Doppler indices of the prostate.

The mean of minimum RI values was found to significantly vary in patients who were less than or equal to 60 years of age with respect to those who were more than 60 years in the benign group. The mean of minimum RI value was significantly higher in patients who were more than 60 years of age than in those who were less than or equal to 60 years of age in the benign group. The mean of minimum RI values in the malignant group was not found to significantly vary with age (Table 2).

On comparing of minimum PI values in patients less than or equal to 60 years of age and those above 60 years, the mean of minimum PI values was marginally significantly higher ($p = 0.067$) in patients who were more than 60 years of age (mean = 1.46) with respect to those who were less than or equal to 60 years (1.05) in the benign group. The mean of minimum PI values in the malignant group was not found to significantly vary with age.

On comparing minimum S/D values in patients less than or equal to 60 years of age and those above 60 years, the mean of minimum S/D values were found to vary in patients who were less than or equal to 60 years with respect to those who were more than 60 years in the benign group. The mean of minimum S/D values were marginally significantly higher

Table 2. Comparison of mean of minimum resistive index (RI) values in patients less than or equal to 60 years of age and those above 60 years

Minimum RI benign			
Age (years)	Mean	SD	Median
≤60 (<i>n</i> = 7)	0.603	0.092	0.610
>60 (<i>n</i> = 26)	0.764	0.199	0.730
<i>p</i> -value		0.014	
Significance	Significant		
Test	Mann–Whitney <i>U</i>		
Minimum RI malignant			
Age (years)	Mean	SD	Median
≤60 (<i>n</i> = 2)	0.70	0.028	0.70
>60 (<i>n</i> = 20)	0.78	0.196	0.745
<i>p</i> -value		0.554	
Significance	Not significant		
Test	Mann–Whitney <i>U</i>		

SD, standard deviation.

($p = 0.077$) in patients who were more than 60 years of age (mean = 3.30) than in those who were less than or equal to 60 years (mean = 2.54) in benign group. The mean of minimum S/D values in the malignant group were not found to significantly vary with age.

On comparing the maximum PSV values in patients less than or equal to 60 years of age and those above 60 years, the mean of maximum PSV values was not found to be significantly associated with age in benign or malignant groups with $p = 0.0183$ (Table 3).

DISCUSSION

This prospective study was carried out to compare the TR spectral Doppler findings between the control group (benign group) and the study groups (malignant group) and to evaluate the performance of these clinical and radiological parameters in differentiating benign and malignant disease processes in the prostate and to evaluate the performance of these clinical and radiological parameters in predicting the aggressiveness of malignant tumour of the prostate.

In this study, all the patients who were included in the study were placed in either the benign group or the malignant group based on the prostatic biopsy reports. In this study, the malignant group was further subdivided into three groups based on the Gleason score—Subgroup A (Gleason score ≤ 5), Subgroup B (Gleason score 6 or 7), Subgroup C (Gleason score ≥ 8). Since Subgroup C had only single case, this group was excluded from the analysis when the benign group was compared with Subgroup A and Subgroup B.

The use of CDUS as a non-invasive means for displaying the vascular anatomy of the prostate gland produces a real-time,

Table 3. Comparison of mean of maximum peak systolic velocity (PSV) values in patients less than or equal to 60 years of age and those above 60 years

Maximum PSV benign			
Age	Mean	SD	Median
≤60 (<i>n</i> = 7)	18.33	4.83	17.50
>60 (<i>n</i> = 26)	21.80	8.76	18.90
<i>p</i> -value		0.183	
Significance	Not significant		
Test	Unpaired <i>t</i> -test		
Maximum PSV malignant			
Age	Mean	SD	Median
≤60 (<i>n</i> = 2)	12.30	6.78	12.30
>60 (<i>n</i> = 20)	22.25	10.24	20.00
<i>p</i> -value		0.199	
Significance	Not significant		
Test	Unpaired <i>t</i> -test		

SD, standard deviation.

reproducible and symmetric flow pattern. In early studies, it was reported that colour flow intensity is generally low or absent in the normal prostate, and focal hypervascularity in the peripheral zone should be regarded as suspicious for malignancy despite the fact that inflammatory lesions have a similar vascularization pattern.^{1,2}

Recently, remarkable progress in colour Doppler ultrasonography technology has increased the sensitivity for identifying and describing normal vascular anatomy in the peripheral zone of the prostate. It has been shown that blood flow to the prostate is supplied mainly by the capsular and urethral branches of the prostatic arteries, supplying two-thirds and one-third of the glandular prostate volume, respectively. The capsular arteries mainly course along the posterolateral border of the prostate, sending branches that perforate the capsule and enter the peripheral zone. The urethral arteries, conversely, course parallel to the prostatic urethra after they enfold into the prostate at the bladder neck.³

In this study, it was found that the mean value and geometric mean were higher for mean PI, mean RI, PSV and S/D in the malignant group than in the benign group, but none of the parameters were found statistically significant between the benign and the malignant groups. Huang and Hsieh⁴ also showed that high-grade prostate cancer tends to have higher RI. They found that the mean age, serum PSA and prostate volume were comparative between the benign and malignant groups, but the differences of RI were statistically significant ($p = 0.029$).

Turgut *et al*⁵ compared the Doppler indices in malignant (Group A) with respect to benign (Group B) subgroups of histopathological outcomes of TR ultrasonographically guided prostate biopsy.

They found that the mean PI value for the CA of Group A was significantly lower than that of Group B. The mean RI and S/D ratio for the CA of Group A were lower than those of Group B despite being statistically insignificant. In another study regarding the role of Colour Doppler in the evaluation of prostate cancer, Ismail *et al*⁶ found increased prostatic blood flow in patients with high-grade prostatic carcinoma.

Kuligowska *et al*⁷ showed that colour Doppler when added to TR greyscale ultrasound findings, the sensitivity for detecting prostate cancer increased from 41.0% to 56.8%, but the PPV decreased from 52.7% to 44.0% because of the low specificity of CDUS. They concluded that greyscale TRUS, even coupled with CDUS, is inadequate for prostate carcinoma screening, and therefore targeted biopsy should always be accompanied by complete sextant biopsy sampling.

Eisenberg *et al*⁸ showed that power Doppler imaging provides little prognostic utility to assess risk in prostate cancer. However, power Doppler imaging might improve the specificity of TRUS in identifying prostate tumours and could have a role in image guidance for focal therapy of prostate cancer. Halpern and Strup⁹ also showed that greyscale and Doppler imaging did not reveal prostatic cancer with sufficient accuracy to avoid sextant biopsy.

In this study, when the Doppler indices were compared on the cancerous side with non-cancerous side in patients who had unilateral malignancy in the malignant group, it was found that the difference in S/D variable was statistically significant between the cancerous and non-cancerous sides and the mean (median) value was higher on the cancerous side ($p = 0.026$) than on the non-cancerous side. The RI and PSV were also higher on the cancerous side, whereas the PI was higher on the non-cancerous side. However, none of these differences were clinically significant.

In the study, comparisons were also made amongst the benign group, Subgroup A and Subgroup B with respect to Doppler indices. It was found that none of the variables differed significantly amongst the various groups.

Helpern *et al*¹⁰ have shown variation in blood flow to the prostate depending upon the patient's posture. They showed increased blood flow on the dependent side of the prostate when the patient was in the lateral decubitus position. Keener *et al*¹¹ carried out a study to determine the effect of ejaculation on prostate blood flow. They found that prostate vascular flow increases dramatically after ejaculation and remains elevated for at least 24 h. Besides, tamsulosin, one of the drugs used to treat BPH also affects the blood flow to the prostate. These observations should also be considered when power Doppler sonography is used to assess for potential hyperaemia in patients suspected of having prostate abnormalities.

In this study, the whole data were also divided into groups based on age (whether less than or equal to 60 years or above 60 years) and compared with various Doppler indices. This was performed to ascertain if age-related factors have a role to play

in affecting blood flow to the prostate and thereby the Doppler indices. Doppler indices (mean of minimum of RI, PI, S/D and maximum of PSV) were evaluated for patients less than or equal to 60 years of age and for those above 60 years separately, and serum PSA levels whether $\leq 4 \text{ ng ml}^{-1}$ or more separately. This was performed separately in benign and malignant category of patients. It was found that the mean of minimum RI was significantly higher in patients of benign category who were more than 60 years of age than in those who were less than or equal to 60 years ($p = 0.014$). The mean of minimum RI was also slightly higher in the malignant group for patients who were more than 60 years of age (mean = 0.78) than in those who were less than or equal to 60 years (mean = 0.70), although the difference was not statistically significant. Mean of minimum PI, S/D were also marginally significantly higher in patients with benign prostatic cancer who were more than 60 years of age than in those who were less than or equal to 60 years. Thus, it was inferred that age-related BPH changes could affect the Doppler indices, and this factor may contribute towards higher RI and PI values in malignant subjects. The correlation of Doppler parameters with age and BPH is likely to have significant clinical implications in monitoring of these patients, as age-related vasculopathy is an important hypothesis for BPH. Spectral Doppler parameters are also expected to be affected by the medical treatment for BPH. This relationship may also be evaluated in future studies which may serve as an important imaging-based parameter to predict the response to medical treatment for BPH and the need for surgery in these patients.

A subset of study patients ($n = 24$) also had pre- or post-biopsy phased-array or endorectal MRI of the prostate. MR spectroscopy and diffusion-weighted MRI studies were also performed in a select group of patients who underwent MRI examination, particularly in patients who were found to have focal lesion on MRI. The variables which were assessed on phased-array or endorectal MRI study of the prostate included focal peripheral zone lesion on T_2 weighted imaging, extracapsular extension, seminal vesicle invasion. Locoregional lymphadenopathy/distant metastases, reversal of choline–citrate ratio and focal restriction of diffusion on diffusion-weighted images. Significant differences between patients who had benign findings on biopsy, as compared with those who had malignancy of the prostate, were found in almost all the variables which were taken into consideration. Significant number of patients ($p = 0.010$) were found showing focal hypointense peripheral zone lesion in the malignant group (7/9) as compared with the benign subjects (3/15). Extracapsular extension with associated seminal vesicle invasion was noted in 3/15 of malignant subjects, while none of the benign subjects had this finding. The study also showed statistically significant differences between benign and malignant category of patients with respect to locoregional lymphadenopathy/metastasis. Four of nine subjects in the malignant group, whereas one patient showed evidence of locoregional lymphadenopathy in the benign category

($p = 0.047$). 6 patients in the malignant group also underwent MR spectroscopy and all of them showed reversal of citrate–choline ratio, whereas 13 patients in the benign category underwent MR spectroscopy and 6/13 showed reversal of citrate–choline ratio. This difference was again statistically significant with $p = 0.044$. Diffusion-weighted imaging was performed in seven subjects who underwent MRI. Restriction of diffusion was noted in three subjects, which turned out to be malignant on biopsy. Facilitated diffusion was noted in the other four patients; these patients on biopsy were found to have BPH and their statistical significance although could not be evaluated because of limited sample size.

There were few limitations which were encountered during the study. The Doppler indices obtained in the study could have been affected by the posture of the patient during the biopsy procedure and the drugs used to alleviate the symptoms of the lower urinary tract of the patients. The Doppler indices could have been affected because of age-induced BPH changes in the prostate as has been proved in this study, thus in turn affecting the utility of this modality in evaluation of prostatic carcinomas. The correlation of Doppler parameters with age and BPH is likely to have significant clinical implication in monitoring of these patients, as age-related vasculopathy is an important hypothesis for BPH. The study comprised of a single patient in Subgroup C of the malignant group, thus leading to the exclusion of this group from statistical analysis.

CONCLUSION

- TR spectral Doppler parameters did not reveal any significant difference in patients with or without prostatic malignancy, irrespective of the Gleason grade. The Doppler indices except for S/D also did not vary significantly between the cancerous side and non-cancerous side in patients who had unilateral malignancy. TR spectral Doppler is therefore unlikely to emerge as diagnostic and prognostic tool for prostate carcinoma.
- Doppler parameters, however, showed significant correlation with age and were lower in younger patients and thus led to the conclusion that age-related BPH changes can affect the blood flow, thereby affecting the Doppler indices of the prostate, and this factor may contribute towards higher RI and PI values in malignant subjects. The correlation of Doppler parameters with age and BPH is likely to have significant clinical implication in monitoring of these patients, as age-related vasculopathy is an important hypothesis for BPH. Spectral Doppler parameters are also expected to be affected by the medical treatment for BPH. This relationship may also be evaluated in future studies which may serve as an important imaging-based parameter to predict response to medical treatment for BPH and the need for surgery in these patients.

ACKNOWLEDGMENTS

To the patients who contributed towards the study.

REFERENCES

1. Rifkin MD, Sudakoff GS, Alexander AA. Prostate: techniques, results, and potential applications of color Doppler US scanning. *Radiology* 1993; **186**: 509–13. doi: <http://dx.doi.org/10.1148/radiology.186.2.7678467>
2. Louvar E, Littrup PJ, Goldstein A, Yu L, Grignon SW. Correlation of color Doppler flow in the prostate with tissue microvasculature. *Cancer* 1998; **83**: 135–40. doi: [http://dx.doi.org/10.1002/\(SICI\)1097-0142\(19980701\)83:1<135::AID-CNCR18>3.0.CO;2-Y](http://dx.doi.org/10.1002/(SICI)1097-0142(19980701)83:1<135::AID-CNCR18>3.0.CO;2-Y)
3. Neumaier CE, Martinoli C, Derchi LE, Silvestri E, Rosenberg I. Normal prostate gland: examination with color Doppler US. *Radiology* 1995; **196**: 453–7. doi: <http://dx.doi.org/10.1148/radiology.196.2.7617860>
4. Huang ST, Hsieh ML. Evaluation of resistance index in patients with prostate cancer. *Anticancer Res* 2008; **28**: 1985–8.
5. Turgut AT, Ölçücüoğlu E, Kosar P, Geyik PO, Kosar U, Dogra V. Power Doppler ultrasonography of the feeding arteries of the prostate gland: a novel approach to the diagnosis of prostate cancer? *J Ultrasound Med* 2007; **26**: 875–83.
6. Ismail M, Petersen RO, Alexander AA, Newschaffer C, Gomella LG. Color Doppler imaging in predicting the biologic behavior of prostate cancer: correlation with disease-free survival. *Urology* 1997; **50**: 906–12. doi: [http://dx.doi.org/10.1016/S0090-4295\(97\)00403-2](http://dx.doi.org/10.1016/S0090-4295(97)00403-2)
7. Kuligowska E, Barish BA, Fenlon HM, Blake M. Predictors of prostate carcinoma: accuracy of gray-scale and color Doppler US and serum markers. *Radiology* 2001; **220**: 757–64. doi: <http://dx.doi.org/10.1148/radiol.2203001179>
8. Eisenberg ML, Cowan JE, Carroll PR, Shinohara K. The adjunctive use of power Doppler imaging in the preoperative assessment of prostate cancer. *BJU Int* 2010; **105**: 1237–41. doi: <http://dx.doi.org/10.1111/j.1464-410X.2009.08958.x>
9. Halpern EJ, Strup SE. Using gray-scale and color and power Doppler sonography to detect prostatic cancer. *AJR Am J Roentgenol* 2000; **174**: 623–7.
10. Halpern EJ, Frauscher F, Forsberg F, Strup SE, Nazarian LN, O’Kane P, et al. High-frequency Doppler US of the prostate: effect of patient position. *Radiology* 2002; **222**: 634–9.
11. Keener TS, Winter TS, Berger R, Krieger JN, Nodell C, Rothman I, et al. Prostate vascular flow: the effect of ejaculation as revealed on transrectal power Doppler sonography. *AJR Am J Roentgenol* 2000; **175**: 1169–72.