Combined Use of Diffusion-Weighted MRI and 1H MR Spectroscopy to Increase Accuracy in Prostate Cancer Detection

OBJECTIVE. The objective of our study was to establish the sensitivity and specificity for prostate cancer detection using a combined 1H MR spectroscopy and diffusion-weighted MRI approach.

SUBJECTS AND METHODS. Forty-two men (mean age ± SD, 69.3 ± 4.7 years) with prostate cancer were studied using endorectal T2-weighted imaging, 2D chemical shift imaging (CSI), and isotropic apparent diffusion coefficient (ADC) maps. Regions of interest (ROIs) were drawn around the entire gland, central gland, and peripheral zone tumor, diagnostically defined as low signal intensity on T2-weighted images within a sextant that was biopsy-positive for tumor. Lack of susceptibility artifact on a gradient-echo B0 map through the slice selected for CSI and no high signal intensity on external array T1-weighted images confirmed the absence of significant hemorrhage after biopsy. CSI voxels were classified as nonmalignant or as tumor (ROI included ≥ 30% or ≥ 70% tumor). Choline–citrate (Cho/Cit) ratios and average ADCs were calculated for every voxel. A plot of Cho/Cit ratios versus ADCs yielded a line of best separation of tumor voxels from nonmalignant voxels. Receiver operating characteristic (ROC) curves were plotted for Cho/Cit ratios alone, ADCs alone, and a combination of the two.

RESULTS. The Cho/Cit ratios were significantly higher (p < 0.001) and the ADCs were significantly lower (p < 0.006) in tumor-containing voxels than in non–tumor-containing voxels. When voxels containing 30% or more tumor were considered positive, the area under the ROC curves using combined MR spectroscopy and ADC (0.81) was similar to that of Cho/Cit alone (0.79) and better than ADC alone (0.66). When voxels containing 70% or more tumor were considered positive and cutoffs to achieve a 90%-or-greater sensitivity chosen, a combination of Cho/Cit and ADC achieved a significant improvement in specificity compared with Cho/Cit alone (p < 0.001) or ADC alone (p < 0.0001).

CONCLUSION. When voxels containing ≥ 70% tumor are considered positive, the combined use of MR spectroscopy and diffusion-weighted MRI increases the specificity for prostate cancer detection while retaining the sensitivity compared with MR spectroscopy alone or diffusion-weighted MRI alone.
zone tissue and benign prostatic hypertrophy. Recently, the use of 3D chemical shift imaging (CSI) has been shown to improve the sensitivity and specificity for tumor detection to 95% and 81%, respectively [7]. Another alternative to T2-weighted MRI is to develop image contrast through "apparent diffusivity," tissue water incoherent displacement over distances of approximately 1–20 µm. Diffusion-weighted MRI is showing potential for improving prostate cancer detection [8–10]. The purposes of this study therefore were to determine the metabolic ratios on 2D chemical shift 1H MR spectroscopy and the apparent diffusion coefficient (ADC) in patients with histologically proven prostate cancer and to establish the sensitivity and specificity of prostate cancer detection using a combined MR spectroscopy and diffusion-weighted MRI approach.

**Subjects and Methods**

**Patient Population**

This was a prospective, single-institution, cross-sectional study with institutional approval from the local research ethics committee and all patients provided informed consent. The study population consisted of 42 patients newly diagnosed with prostate cancer on the basis of an elevated PSA level and positive findings for cancer on transrectal sonographically guided biopsy who were willing to undergo additional endorectal scanning. There was no history of pelvic radiation therapy, thermal therapy to the prostate, or chemotherapy. All patients had a clinical stage less than or equal to T3 N0 M0 (23 were T1c, eight were T2a, two were T2b, and nine were T3a).

A minimum of six cores had been obtained from each patient. The number of positive cores varied from one to four, and Gleason grade varied from 6 to 8. Patients ranged in age from 60 to 78 years (mean ± SD, 69.3 ± 4.7 years) with PSA values ranging from 0.45 to 45 ng/mL (median, 10.2 ng/mL; lower and upper quartiles, 6.0 and 16.2 ng/mL). Over a 13-month period, patients underwent diffusion-weighted MRI and 1H MR spectroscopy of the prostate during the same examination as the routine staging MRI examination performed at a median of 21 days (lower and upper quartiles, 12 and 49 days) after the most recent biopsy.

**MRI and 1H MR Spectroscopy**

MR studies were performed on a 1.5-T unit (Intera, Philips Medical Systems) using an endorectal coil with a balloon inflated with 55 ml of air. Hyoscine butyl bromide (20 mg) was administered intramuscularly immediately before centering the patient in the scanner to reduce peristalsis: The use of hyoscine butyl bromide is routine at our institution for abdominopelvic MRI, and hyoscine butyl bromide is preferred to glucagon because of its more effective antiperistalsis capability. None of our patients had a history of urine retention. Although hyoscine butyl bromide is contraindicated in patients with large prostates and urine retention, given intramuscularly at this dose, we have seen no cases of urine retention in the more than 500 prostate examinations we have performed.

Conventional T2-weighted turbo spin-echo (TSE) images were obtained in three orthogonal planes (TSE; TR/TE, 2,000/90; echo-train length, 16; 2 signal averages) with a 256 × 512 matrix, 3-mm slice thickness, no gap, and a 14-cm field of view; the total imaging time was 12 minutes. Echo-planar diffusion-weighted images (TR/TE, 2,500/69) with b values of 0, 300, 500, and 800 s/mm² were obtained transverse to the prostate and parallel to the corresponding set of T2-weighted images. The phase-encoding gradient was from left to right to minimize motion artifacts in the prostate. Twelve 4-mm-thick slices (no gap; 20-cm field of view; matrix, 128) provided coverage of the prostate with an image acquisition time of 1 minute 24 seconds. ADC maps were generated using the system software.

In addition, CSI was performed over a single slice transverse to the prostate, using a thickness of 15 mm and a 16 × 16 grid (voxel size, 8.75 × 8.75 × 15 mm³). The slice was selected by identifying a focal low-signal-intensity abnormality on the axial T2-weighted scans within a sextant that was biopsy-positive for tumor and centering there. Signal collection was restricted to voxels over the prostate using the point-resolved spectroscopy (PRESS) localization technique (TR/TE, 1,500/20), and an automated shifting method over the PRESS volume used scanner software to adjust the x, y, and z axis gradients in small increments and test for the best line shape. Lipid suppression, by frequency-selective inversion before PRESS excitation, and water suppression, using band-selective inversion with gradient dephasing (BASING [11]), were included. Regional saturation was not required due to acceptably low levels of lipid contamination in both the central and peripheral voxels. Data acquisition took 12 minutes. The spectroscopy data were voxel-shifted to align the CSI data set with the PRESS box and were exported for analysis with LCModel fitting package (Stephen Provencher, Inc.) [12] using a basis set containing metabolite spectra from choline, creatine, and citrate. B0 maps (dual gradient-echo; TR/first-echo TE, second-echo TE, 50/7.6, 17.6) were obtained before MR spectroscopy in all cases to ensure that there was no significant susceptibility artifact from hemorrhage within the prostate.

After endorectal MRI and MR spectroscopy, an external pelvic phased-array coil was used to acquire axial T1-weighted (TSE; TR/TE, 650/7) and T2-weighted (TSE; TR/TE effective, 5.396/80) images through the pelvis as part of the routine clinical staging scan. The B0 maps and T1-weighted images confirmed the absence of any significant postbiopsy hemorrhage in this patient cohort.

**Data Analysis**

The five consecutive T2-weighted slices that corresponded to the thicker CSI slice were identified. On each of these, ROIs were drawn by a radiologist, who had 8 years’ experience in interpreting prostate MRI at the time of the study, for the entire prostate; central gland; and tumor, defined as low-signal-intensity areas within the peripheral zone in a sextant that was biopsy-positive for tumor. Isointense tumors were thus not included in this analysis. The median tumor ROI size was 1.45 cm², with lower and upper quartiles of 0.69 and 2.1 cm². The absence of significant postbiopsy hemorrhage was confirmed on the B0 maps and T1-weighted external array images.

The first criterion chosen for inclusion of a voxel in the analysis was that the overall signal-to-noise ratio (SNR) calculated by the LCModel fitting package [12] in each spectrum should be greater than 2. The SNR in the LCModel is defined as the maximum signal within the frequency range of interest in the baseline-corrected spectrum divided by twice the root-mean-square residuals. A possible alternative criterion that both the choline and citrate signals must satisfy a specific Cramer-Rao minimum variance bound would result in voxels containing significant tumor volume being rejected due to an absence of citrate. The criterion chosen led to the inclusion of spectra from a total of 511 voxels in 42 patients. A second criterion was that the voxel included should be formed of at least 70% prostate gland as determined by the ROIs in the five corresponding T2-weighted slices. This process eliminated an additional 113 voxels, leaving a total of 398 voxels for inclusion in the analysis.

Tumor voxels were defined using two different thresholds: ≥30% or ≥70% tumor based on proportion of tumor ROI identified on the T2-weighted image within the voxel. Using the biopsy-supported ROIs outlined on the T2-weighted scans, the 398 CSI voxels were classified into nontumor peripheral zone (0% tumor and ≥70% peripheral zone, n = 24), nontumor central gland (0% tumor and ≥70% central gland, n = 180), nontumor mixed voxels (0% tumor, <70% central gland, <70% peripheral zone, n = 68), and tumor (tumor ROI occupying ≥30% [n = 47] or ≥70% [n = 15] of the voxel). The small number of nontumor peripher al zone voxels is due to central gland enlarge-
ment in this age group, resulting in predominantly central gland or mixed voxels. Thus, 319 and 287 of the 398 voxels were included in the ≥30% tumor and ≥70% tumor analyses, respectively; the remaining voxels contained smaller tumor volumes and were not considered. ADC maps were coregistered with high-resolution T2-weighted images and CSI spectroscopy. Metabolite levels and their ratios and average ADCs were calculated for every voxel classified on MR spectroscopy (Fig. 1). The LCModel fitting package [12] calculated the Cramer-Rao minimum variance bounds (% SD) for each peak; a peak was regarded as significant if this value was less than 20%.

**Statistical Analysis**

Statistical analysis of the data was performed using SPSS software (version 11.0, SPSS) for Windows (Microsoft) and in-house software developed using Interactive Data Language (IDL, ITTVIS Ltd.). Because clear separation between choline and creatine was obtained in our data, the ratios of Cho/Cit (rather than needing to use [choline + creatine] / citrate) and ADC from each voxel type (nontumor, ≥30% tumor, and ≥70% tumor) were computed and compared. Normality plots and the Shapiro and Francia test for normality showed the data from the Cho/Cit ratios were nonparametric, whereas the data from the ADC maps were parametric. Therefore, the Cho/Cit data were normalized by taking the log (to base 10) of values, and both sets of data were investigated using parametric statistical tests. One-way analysis of variance tests were used to detect differences between

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**Fig. 1**—75-year-old man with prostate cancer. A, Endorectal T2-weighted transverse image through mid prostate shows well-defined low-signal-intensity region in peripheral zone on left (arrows), within sextant that was positive for tumor on biopsy. B, Radiologist-determined region of interest around tumor and overlay of voxels for MR spectroscopy acquisition are seen. C and D, Hydrogen-1 MR spectroscopy from a voxel of nonmalignant peripheral zone on right (signal-to-noise ratio [SNR] = 3) (D). Gray line shows data and black line represents fit using LCModel (Stephen Provencher, Inc.) (both smoothed for display using 5-point weighted average). Increase in choline (Cho) (3.2 ppm) and decrease in citrate (Cit) (2.6 ppm) are seen in D compared with C. In C, Cho/Cit ratio is 0.31; in D, 0.45. AU = arbitrary units. (Fig. 1 continues on next page)
Reinsberg et al.

Fig. 1 (continued)—75-year-old man with prostate cancer. 

E and F, Apparent diffusion coefficient (ADC) map at native resolution (E) and ADC map resampled to match MR spectroscopy resolution (F) show restricted diffusion in left peripheral zone (mean ADC: tumor-containing voxel, $0.8 \times 10^{-3}$ mm$^2$/s; non–tumor-containing voxel, $1.24 \times 10^{-3}$ mm$^2$/s).

nontumor and either $\geq 30\%$ tumor or $\geq 70\%$ tumor voxels. The Student’s $t$ test for independent samples was used to compare peripheral zone or central gland voxels with tumor voxels. Significance tests were two-sided, and a $p$ value of less than 0.05 was chosen as the criterion for statistical significance.

Sensitivities and specificities for identifying tumor within a voxel using MR spectroscopy alone or diffusion-weighted imaging alone were calculated. Receiver operating characteristic (ROC) curves were used to show the power of the Cho/Cit ratios and ADCs as predictors of tumor at histology. ROC curves considering voxels containing $\geq 30\%$ tumor and those considering voxels containing $\geq 70\%$ tumor were plotted for Cho/Cit ratios alone, ADCs alone, and a combination of the two. For the latter, a 2D plot of the log$_{10}$ Cho/Cit ratios versus ADCs was obtained, and a line that best separated tumor from nontumor voxels was drawn (Fig. 2). The position of this line was determined by varying the angle to the horizontal in small incremental steps and determining the angle that resulted in the ROC curve with the highest area under the curve (AUC).

One-sided significance tests were used to compare differences in the sensitivity and specificity of the combination of Cho/Cit ratio with ADC over either technique alone, and a $p$ value of less than 0.05 was chosen as the criterion for statistical significance.

Results

Figure 1 shows a focal low-signal-intensity lesion on T2-weighted imaging that was positive for tumor at biopsy with corresponding spectra from CSI voxels and an ADC map. The Cho/Cit ratio was higher in tumor-containing voxels than in nontumor-containing voxels (Table 1). Univariate analysis of variance for each tumor threshold showed that the Cho/Cit ratios were significantly higher in both classes of tumor-containing voxels than in nontumor-containing voxels ($p < 0.001$). When $\geq 30\%$ tumor within a voxel was considered positive, an ROC curve of the relation between the log$_{10}$ (Cho/Cit) and the diagnosis of tumor showed the AUC to be 0.79 (95% CI, 0.71–0.88; Fig. 3A). For this 30% threshold, the optimum discrimination suggested by the ROC curve was at a cutoff Cho/Cit ratio of $> 0.07$ (log$_{10}$[Cho/Cit] = –1.15); voxels

Fig. 2—Scatterplot of choline–citrate (Cho/Cit) ratio versus apparent diffusion coefficient (ADC) for MR spectroscopy voxels with minimum signal-to-noise ratio of 2. Tumor voxels (■) were those that contained 70% or more tumor, as outlined on T2-weighted images. Peripheral zone voxels (×) are non–tumor-containing voxels with at least 70% peripheral zone, and central gland voxels (+) are non–tumor-containing voxels with 70% or more central gland. Non–tumor-containing voxels, which do not reach either of these classification thresholds, are labeled peripheral zone, central gland, or central gland–peripheral zone mixed (■). Line optimally separating tumor from nontumor voxels is shown.
TABLE 1: Metabolite Ratios and Apparent Diffusion Coefficients (ADCs) in the Five Classes of Voxel

<table>
<thead>
<tr>
<th>Class of Voxel</th>
<th>Choline/Citrate (mean ± SD [range])</th>
<th>ADC × 10⁻³ mm²/s (mean ± SD [range])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peripheral zone</td>
<td>0.065 ± 0.052 (0–0.237)</td>
<td>1.51 ± 0.27 (1.05–2.05)</td>
</tr>
<tr>
<td>Central gland</td>
<td>0.077 ± 0.074 (0–0.721)</td>
<td>1.31 ± 0.20 (0.82–1.78)</td>
</tr>
<tr>
<td>Mixed voxels</td>
<td>0.11 ± 0.31 (0–2.44)</td>
<td>1.34 ± 0.24 (0.86–1.86)</td>
</tr>
<tr>
<td>Tumor ≥ 30% of voxel</td>
<td>0.814 ± 2.002 (0 to ∞)</td>
<td>1.19 ± 0.24 (0.71–1.93)</td>
</tr>
<tr>
<td>Tumor ≥ 70% of voxel</td>
<td>0.918 ± 1.276 (0.06 to ∞)</td>
<td>1.03 ± 0.18 (0.74–1.38)</td>
</tr>
</tbody>
</table>

Univariate analysis of variance showed that the ADCs were significantly lower in both classes of tumor-containing voxels than in the non–tumor-containing voxels (p < 0.006). There were also significant differences between normal peripheral zone and central gland voxels (p < 0.001) and between voxels containing ≥ 30% tumor and those containing ≥ 70% tumor (p < 0.01). When ≥ 30% tumor within a voxel was considered positive, an ROC curve of the relation between the ADC and the diagnosis of tumor showed the AUC to be 0.66 (95% CI, 0.58–0.75; Fig. 3A). No cutoff value of ADC could be chosen to achieve at least 70% sensitivity and specificity. When voxels containing ≥ 70% tumor were considered, the AUC was 0.85 (95% CI, 0.76–0.95) and using a cutoff of 1.26 × 10⁻³ mm²/s, tumor could be predicted with a sensitivity of 93.3% and specificity of 57.4% (Table 2). Sensitivity and specificity for ≥ 30% tumor voxels using this ADC cutoff were 67.3% and 59.9%, respectively.

A combined analysis of Cho/Cit ratios and ADCs was also done. When ≥ 30% tumor within a voxel was considered positive, an ROC curve of the relation between log₁₀(Cho/Cit) and ADC and the diagnosis of tumor showed the AUC to be 0.81 (95% CI, 0.73–0.88), and there was no improvement compared with the Cho/Cit curve alone (Fig. 3A). When ≥ 70% tumor within a voxel was considered positive, an ROC curve of the relation between a combination of log₁₀(Cho/Cit) and ADC and the diagnosis of tumor showed the AUC to be 0.98 (95% CI, 0.95–0.995) (Fig. 3B and Table 2), which achieved a better separation of tumor-containing and non–tumor-containing voxels than ADC alone or log₁₀(Cho/Cit) alone (p < 0.05). The optimal separation for the ≥ 70% tumor-containing voxels is described by the relationship log₁₀(Cho/Cit) = 1.946 × ADC – 3.088 (Fig. 2). Using this dividing line gives a sensitivity of 93.3% and a specificity of 90.9% for tumor diagnosis.

For comparison, a similar optimized separating line for the ≥ 30% tumor voxels given by the relationship log₁₀(Cho/Cit) = 0.910 × ADC – 0.102 resulted in a sensitivity of 70.2% and a specificity of 83.5%. Because achieving > 90% sensitivity was used as the criterion for comparison, it was not possible to test for an improvement in sensitivity. However, for ≥ 70% tumor-containing voxels, specificity of the combination was significantly improved compared with either Cho/Cit ratio alone (p < 0.0001) or ADC alone (p < 0.0001). With a sensitivity of 100% for the combination of Cho/Cit and ADC, a specificity of 90% could be achieved (Table 2).

To assess the quality of the ROC curves used for predicting the sensitivity and specificity tumor presence, the AUC was plotted against tumor fraction in the voxel (Fig. 4). The AUC values increased with increasing tumor fraction in the voxel, consistent with a reduced contamination of the data from nonmalignant tissue within the voxel.

Discussion

Our study shows that when voxels containing ≥ 70% tumor are considered positive for tumor, the combination of MR spectroscopy and diffusion-weighted MRI increases the specificity of prostate cancer detection while retaining sensitivity compared with MR spectroscopy alone or diffusion-weighted MRI alone. The altered cellular metabolites from tumor-containing voxels and changes in ADC...
TABLE 2: Sensitivities, Specificities, and Accuracies of Choline–Citrate (Cho/Cit) Ratio Alone, Apparent Diffusion Coefficient (ADC) Alone, and a Combination of the Two for the Detection of Tumor in the Prostate

<table>
<thead>
<tr>
<th>Criterion to Test Positive for Cancer</th>
<th>Tumor ≥ 30% of Voxel</th>
<th>Tumor ≥ 70% of Voxel</th>
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<tbody>
<tr>
<td></td>
<td>Sensitivity (%)</td>
<td>Specificity (%)</td>
</tr>
<tr>
<td>Log_{10}Cho/Cit &gt; optimum cutoff value</td>
<td>80.9</td>
<td>64.3</td>
</tr>
<tr>
<td>ADC &gt; optimum cutoff value</td>
<td>67.3</td>
<td>59.9</td>
</tr>
<tr>
<td>Combined: log_{10}Cho/Cit &gt; optimum cutoff value</td>
<td>70.2</td>
<td>83.5</td>
</tr>
</tbody>
</table>

Note—Optimum cutoff values for ≥30% voxels: log_{10}Cho/Cit = –1.15, ADC = 1.26 × 10^{-3} mm²/s, combined log_{10}Cho/Cit and ADC = (0.910 × ADC) –2.102. Optimum cutoff values for ≥70% voxels: log_{10}Cho/Cit = –1.088, ADC = 1.26 × 10^{-3} mm²/s, combined log_{10}Cho/Cit and ADC = (1.946 × ADC) –3.088. AUC = area under the receiver operating characteristic curve.

AUC = area under the curve (AUC) as function of tumor fraction in voxel. As expected, there is increase in AUC with increasing tumor fraction for all parameters measured due to reduction of normal tissue in tumor voxel. Choline–citrate ratio alone (dashed line), apparent diffusion coefficient alone (dotted line), and combination of the two (solid line) are shown.

Fig. 4—Quality of receiver operating characteristic curves as measured by area under curve (AUC) as function of tumor fraction in voxel. As expected, there is increase in AUC with increasing tumor fraction for all parameters measured due to reduction of normal tissue in tumor voxel. Choline–citrate ratio alone (dashed line), apparent diffusion coefficient alone (dotted line), and combination of the two (solid line) are shown.
sion of water and lipid. Dual-band BASING and spectral–spatial pulses have been recommended to solve this problem [22]. However, we found that the combination of a simple frequency-selective inversion pulse followed by a relaxation delay before the PRESS localization reduced signals from lipid to a satisfactory level. Also, although some authors have found it helpful to use saturation bands to reduce lipid contamination from outside the slice [22], visual inspection of our data showed no sign of large lipid peaks. In addition, in two patients scanned with and without saturation bands, a comparison of 40 voxels (with sufficient SNR to give < 20% uncertainty in peak areas) showed no significant difference (p > 0.1) in mean metabolite values.

The sensitivity of MR spectroscopy, however, may be affected by cancer grade: A study by Zakian et al. [23] suggests that small low-grade tumors may be missed using 3D MR spectroscopic imaging because the severity of metabolite alteration correlates with tumor aggressiveness. There was a trend toward increasing the [(Cho + creatine) / Cit] value with increasing Gleason score in lesions identified correctly with MR spectroscopic imaging. In our study, all but one of the tumors had a Gleason grade > 6.

More recently, diffusion-weighted MRI has also been evaluated for its ability to show the prostate, primarily in animal models. An increase in the ADC has been noted in a subcutaneously implanted rat prostate tumor after chemotherapy [24]. Using nuclear MR microscopy, Artemov et al. [25] showed different diffusion rates for two prostate cancer cell lines. A study at 4.7 T showed improved prostate tumor detection in transgenic mice using diffusion-weighted imaging compared with T2 mapping [26]. Preliminary work on diffusion-weighted imaging of the prostate in vivo in humans has shown differences between tissue types warranting clinical investigation [8, 9, 27, 28], and a recent study of 60 patients showed that the addition of diffusion-weighted imaging to conventional T2-weighted imaging significantly improved tumor detection [8].

In the present study, we were assessing diffusion-weighted imaging at a much lower resolution with a voxel size commonly used for MR spectroscopy. Despite this, the addition of the diffusion-weighted imaging data to the MR spectroscopy data significantly improved specificity to 90%. Because it is easy to implement, available on most standard MR scanners, and incurs little time penalty (1.5 minutes), it is worth incorporating diffusion-weighted imaging into the standard prostate MRI and MR spectroscopy protocol. In this study, tumor foci of 1 cm³ within a voxel could be identified with a high degree of certainty.

The use of an air-filled balloon endorectal coil potentially has several technical limitations. The local field inhomogeneities cause difficulties in shimming and result in line broadening. Further, our diffusion-weighted images were acquired with an echo-planar readout, which leads to some distortion in the neighborhood of tissue boundaries where there is a discontinuity in magnetic susceptibility. There is also sometimes a shift in the phase-encode direction owing to a slight offset of the water resonance frequency. We have previously quantified both distortions compared with a standard spin-echo readout, which yielded a bulk shift of 0.11–4.28 mm (median, 1.10 mm) and a residual disagreement between echo-planar and T2-weighted prostate outlines of 1.2 ± 0.5 mm (mean ± SD) [27]. These are small compared with the spectroscopic voxel size.

Although it would have been preferable to perform MR spectroscopy 6–8 weeks after biopsy, the examination was done as an addition to the staging MRI scan. This was required within a shorter time frame to implement clinical management. A further limitation of this study is that malignant lesions isointense to normal peripheral zone on T2-weighted images were not included in the analysis. It was not possible to include those regions without histologic proof of their involvement with tumor. Similarly, it was not possible to include tumor within the central gland because differentiation of benign from malignant low-signal-intensity regions was not possible. The error inherent in sampling on endorectal sonographically guided biopsy would make it difficult to place ROIs over a described location with any degree of certainty. There is also a false-positive rate associated with other benign abnormalities on T2-weighted MRI—conditions including prostatitis, fibrosis, intraglandular dysplasia, and glandular atrophy—that also are low in signal intensity and may mimic cancer [29]. To further establish the sensitivity and specificity of the technique, therefore, correlation with prostatectomy specimens is warranted.

References

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Reinsberg et al.


FOR YOUR INFORMATION

The reader’s attention is directed to the article by Graser et al., “Per-Sextant Localization and Staging of Prostate Cancer: Correlation of Imaging Findings with Whole-Mount Step Section Histopathology,” which appears on page 84 of this issue.