

Ultrasonic tissue-type imaging of prostate cancer

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Prostate cancer (PCa) is diagnosed by means of needle biopsies typically guided by transrectal-ultrasound (TRUS). TRUS provides an inexpensive and effective means of visualizing gland anatomy and systematically directing each biopsy needle to a specific region within the gland. However, identification of cancerous regions in the prostate cannot be performed reliably using TRUS imaging or any other standard imaging modality. As a result, the majority of prostate biopsies are acquired blindly, with little or no knowledge of where cancerous tissue is located. Analysis of repeat-biopsy results for patients with initially negative biopsies indicates that half the cancers may be missed using standard biopsy-guidance imaging methods. Furthermore, because cancerous regions cannot be imaged reliably, region-specific focal treatment is not yet possible; all standard treatment procedures for gland-confined disease must be applied to the entire prostate. Prostate-tissue characterization based on a combination of ultrasound spectral (USS) parameters and clinical parameters that are classified by non-linear analysis methods, such as artificial neural networks (ANNs) and support-vector machines (SVMs), is showing encouraging potential for distinguishing cancerous from non-cancerous tissue in the prostate. These classification methods provide a means of generating tissue-type images (TTIs) that can reliably image cancerous regions in the prostate and provide information for guiding biopsies and planning and performing focal therapy for prostate-cancer treatment.

During required, TRUS-guided, biopsy procedures, we acquired US echo signals from the biopsied scan plane in the prostates of 64 patients at the Veterans Affairs Medical Center in Washington, DC. The majority of the subject population was Black. Echo-signal data were acquired immediately prior to firing the biopsy needle to prevent data degradation by needle-caused trauma and hemorrhage. Concurrently, the examining urologist assigned a level of suspicion (LOS) for cancer at the biopsy site based on the appearance of the conventional US image and any additional information that was available, e.g., the prostate-specific-antigen (PSA) level. These LOS assignments later served as a baseline for evaluating classifier performance. We then computed US spectra (USS) from echo signals site matched to the known location of the biopsied tissue. We used two USS parameters along with PSA levels to train an ANN classifier with biopsy-core histology as the gold standard. Multi-layer perceptrons (MLPs) and radial-basis functions (RBFs) were considered. ROC methods provided a means of selecting the most-effective ANN configuration. Using the best-performing classifier configuration, we created a lookup table for translating USS-parameter and PSA values into cancer-likelihood scores on a pixel-by-pixel basis in TTIs. Subsequently, we evaluated alternative classification tools such as SVMs and compared classification performance to the best ANN.

Our best US-based ANN classification was provided by an MLP and resulted in an ROC area under the curve (AUC) of 0.84 ± 0.02 ; in comparison, the baseline, B-mode-based classification resulted in an area of 0.66 ± 0.03 . The standard errors in the AUC estimates were very small compared to the area difference, and the 95% confidence intervals did not overlap. The more-robust SVM classifier produced an ROC AUC of 0.88, and we will investigate this classification method further because of its numerous attributes compared to ANNs. Comparison of the ANN and SVM ROC curves to the B-mode ROC-curve implied that at least 50% more cancers could be detected if US-based TTIs were used to guide biopsies. These ROC results are entirely consistent with previous results derived from a predominantly white subject population consisting of nearly 300 patients at the Memorial Sloan-Kettering Cancer Center in New York, NY. TTIs generated from US data revealed cancerous regions in prostate tissue that were unrecognized in conventional images. Examples are illustrated in the transverse-plane images of Fig 1 below. Figure 1 shows a gray-scale TTI generated from echo-signal data acquired in the operating room prior to prostatectomy; it clearly displays a previously unrecognized, 12-mm, anterior tumor; pixel brightness increases with cancer likelihood. Figure 1 also includes an approximately matching plane from prostatectomy histology; it shows the anterior tumor and several smaller PCa foci and a posterior region of intraepithelial neoplasia.

Prostate TTIs based on non-linear classification of combined USS and clinical parameter values show promise for improving detection and management of PCa. If future clinical trials verify results obtained to date, then a powerful, inexpensive, imaging method will become available for guiding biopsies, planning treatment, and targeting therapy of this disease.

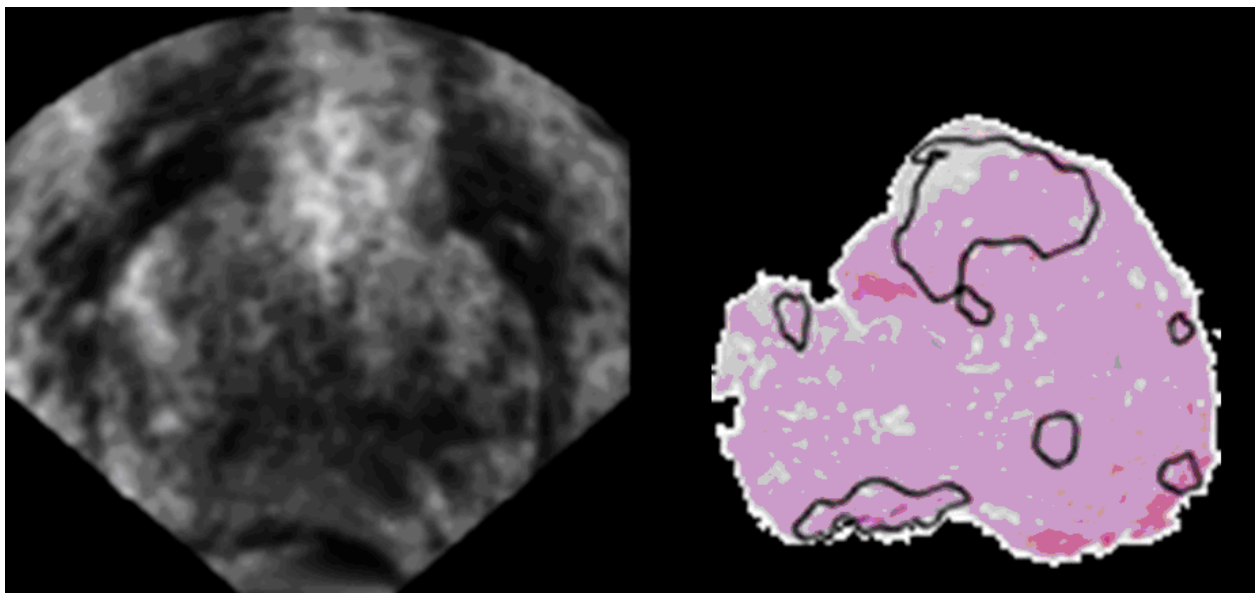


Fig. 1 TTI and histology of an anterior tumor. TTI pixel brightness indicates cancer likelihood and reveals a highly suspicious anterior region. Histology shows a previously unrecognized anterior tumor.

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