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Update on Prostate Imaging

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Successful and accurate imaging of prostate cancer is integral to its clinical management from detection and staging to subsequent monitoring. Various modalities are used including ultrasound, computed tomography (CT) and magnetic resonance imaging (MRI), with perhaps the greatest advances seen in the field of magnetic resonance.

Ultrasound

Since the introduction of grayscale transrectal ultrasound imaging for prostate cancer in the late 1960's (1), technical developments have improved image quality. However, in conjunction with biopsy, it remains a test with widely variable sensitivity and specificity, ranging from (50–92%) and (46–91%) respectively (2,3). Furthermore, it has been shown that the positive predictive value of transrectal ultrasound guided biopsies may be as low as 15.2%, compared with 28% for digital rectal exam (4). This is attributed to variable tumor echogenicity, the multifocal nature of disease, concomitant inflammatory or pathological processes, and operator inexperience.

While 3-D ultrasonography, color Doppler and microbubble contrast agents have been shown to improve sensitivity, specificity and accuracy to varying degrees (5–7), ultrasound remains primarily a cost-effective imaging modality to guide trans-rectal biopsy. Additionally it serves an adjunct role during seed placement in brachytherapy, and targeted therapies such as MRI guided focused ultrasound (8) and cryoablation of focal lesions.

Elastography relies on detecting variance in tissue compliance, generated by compression and relaxation, used in conjunction with an imaging modality such as ultrasound or MRI. With ultrasound, it exhibits a sensitivity and specificity of over 75%, and a positive predictive value of up to 88% (9–11).

Computed Tomography

While CT has a limited role in the detection of prostate cancer, in patients with highly elevated PSA levels, it may be a useful modality to assess nodal involvement, capable of

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scanning the entire body in a short period of time. However, MRI and dedicated bone scans have been shown to be superior in their assessment of bone metastases (12).

Positron emission tomography (PET) relies on relatively increased cellular metabolism of radiotracer by tumor cells, to identify loci of tumor or recurrence. It has not been widely used in prostate cancer, however a role is emerging for loco-regional nodal staging, detection of recurrent and metastatic disease in biochemical relapse, and assessment of tumor response to therapy (13).

Magnetic Resonance Imaging

Since its introduction into clinical practice, magnetic resonance imaging has provided a previously unparalleled opportunity to visualize tissue detail without patient exposure to ionizing radiation. The myriad of refinements that have been necessary to increase signal to noise ratio and achieve higher spatial, spectral and temporal resolution are beyond the scope of this article, however consensus is being reached within the literature that a 3-Tesla strength magnetic field, and use of a pelvic phased-array coil, or endorectal pelvic phased-array coil represent the current gold standard (14–16).

MRI itself encompasses a variety of sequences, each suited to expose a particular anatomical or pathophysiological feature of disease. Multi-parametric imaging is therefore necessary to fully utilize the potential of MR and to accurately stage and monitor disease (17–19). Standard T1 and T2 weighted images are used in concert to define morphology and distinguish between areas of signal drop arising from foci of cancer as opposed to artifact related to hemorrhage or inflammatory change from recent biopsy.

Additional functional sequences such as Dynamic Contrast Enhanced (DCE), Diffusion Weighted (DWI) and MR Spectroscopy (MRS) are used, each of which provides unique information on tissue characteristics (20–22). DCE acquires data on tissue wash-in and washout of contrast, relying on pathophysiologic principles that tumors display increased angiogenesis, thus are expected to show early and increased enhancement. Graphical representations of the data are generated, from which computer assisted quantitative analysis is derived.

DWI records the microscopic motion of water molecules within tissue, theorizing that poorly differentiated cancers exhibit marked tissue heterogeneity, and decreased water movement. An apparent diffusion coefficient (ADC) map is generated, and ADC values then acquired, assisting in detection of foci of disease. Spectroscopy examines cellular metabolism within single or multiple voxels, using high levels of choline and low levels of citrate as likely areas of cancer. Meta-analyses have shown in certain patient populations, MRS carries high specificity, but low sensitivity, suggesting a role, at this time, as a rule-in test for low-risk patients (23).

Finally, various novel radiotracers and positron emitting radio-isotopes have been proposed, including 11Choline, 18F-fluorocholine and 11 C-acetate, and 18F-fluoride, 11C-methionine and 11C-tyrosine, respectively. These together with radio-labelled monoclonal antibodies against specific cancer cell surface antigens, may represent more sensitive means of tumor detection, either for staging purposes or evaluating biochemical recurrence (24,25).

Currently, optimal imaging of prostate cancer involves multi-parametric MRI at 3-Tesla, incorporating T1 and T2 weighted sequences, together with DWI and DCE. It has been proposed that pre-biopsy MRI may obfuscate the potential confusion generated by residual blood products, potential distortion of native tissue and local inflammation (26,27). However, given the increasing frequency of this disease and the potential cost burden of

obtaining an MRI due to elevated prostate specific antigen (PSA) and/or and abnormal prostate digital exam, it is unlikely to be a viable solution. Ongoing research will attempt to better delineate foci of disease and achieve greater sensitivity and specificity, with the use of more sophisticated imaging techniques, post-processing software and novel bio-molecular markers.

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