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Does Computed Tomography or Positron Emission Tomography/Computed Tomography Contribute to Detection of Small Focal Cancers in the Prostate?

Michael M. Li,¹ Maxim Rybalov, M.D.,² Masoom A. Haider, M.D., FRCPC,¹ and Igle J. de Jong, M.D., Ph.D.²

Abstract

Prostate cancer is considered to be a multifocal tumor in the majority of patients. Based on histologic data after prostatectomy, there is a growing insight that a considerable number of men who receive a diagnosis in the contemporary setting of prostate-specific antigen screening have unilateral or unifocal disease. With this, the current concept of whole-gland therapy has come into discussion. The need for improvement of intraprostatic tumor characterization is clear. Molecular imaging is one of the areas of research on this aspect. The clinical indications for positron emission tomography (PET)/CT have increased rapidly in the field of oncology and are largely based on fluorodeoxyglucose (FDG) PET. Both conventional CT and FDG PET, however, cannot detect prostate cancer foci <5 mm within the prostate. Dynamic contrast-enhanced CT involves imaging a region of interest rapidly (usually <10 seconds between images) during a bolus intravenous injection of a contrast agent. Through analysis of the contrast enhancement time curves, it is possible to distinguish tissues with different microvascular properties such as cancer. The technologic aspects of both imaging techniques and the clinical results of ¹¹C-choline PET/CT for intraprostatic tumor characterization are discussed. Based on preliminary studies, dynamic contrast-enhanced (DCE)-CT may be a useful tool for localization of prostate tumors and, perhaps more importantly, quantification of therapeutic response in prostate cancer. Validation work is necessary, however, to define its accuracy and role in therapeutic paradigms such as focal therapies, particularly given the current accuracy of MRI. In the future, combining DCE-CT with CT or ¹¹C-choline PET/CT may be an alternative to MRI, offering a combination of quantitative parameters that may correlate to tumor prognosis as well as cancer localization for focal therapy.

Introduction

ACCORDING TO CURRENT European Association of Urology and American Urological Association (AUA) guidelines, CT alone is not recommended for the staging of newly diagnosed cancer because it is not sufficiently reliable for the assessment of local tumor staging.¹ CT shows limited sensitivity (30%–50%) and overall accuracy of 67% to 70%.^{2,3} Because of the extremely low likelihood of positive findings in new patients with a prostate-specific antigen (PSA) level <20 ng/mL (1%) or with a Gleason score <8 (1.2%), guidelines state that CT is only indicated in patients in advanced stages who are likely to have lymph node findings present.⁴ In particular, CT may be considered when the PSA level is >20 ng/mL or when the Gleason score is ≥8.⁵

CT planning is recommended for external beam radiotherapy.^{1,5} In particular, the AUA recommends CT in com-

bination with a bone scan for patients undergoing external beam radiotherapy with a Gleason score ≥8 or a PSA level >20 ng/mL.⁵ In addition, multiple CT scans may be of value in determining prostate motion during the course of this therapy.⁶ Preliminary research also shows that regular CT scans hold promise as a tool for improved tumor targeting and prostate positioning during image-guided intensity-modulated radiotherapy.^{7,8} The guidelines on the indications for PET in prostate cancer have not been defined.

We review the recent developments in visualization and localization of prostate cancer using dynamic contrast enhanced (DCE)-CT and positron emission tomography (PET)/CT.

Localization of Prostate Cancer with DCE-CT

DCE imaging, sometimes referred to as perfusion imaging, involves imaging a region of interest rapidly (usually <10

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seconds between images) during a bolus intravenous injection of a contrast agent.⁹ Through analysis of the contrast enhancement time curves, it is possible to distinguish tissues with different microvascular properties (Fig. 1). Angiogenesis has been known to be an important process in the growth, proliferation, and metastasis of cancers.^{9,10} Most tumors, including prostate cancer, exhibit alterations in permeability and microvessel density when compared with the normal peripheral zone.¹¹ DCE-MRI studies have shown that prostate cancer typically exhibits higher peak enhancement and washout compared with the surrounding normal gland.¹² This has been studied most in whole-mount correlation studies, with DCE-MRI showing good localization specificities (88%–97%) and accuracies (87%–92%).^{13–15} This differential enhancement of prostate cancer suggested a properly timed helical CT may allow for cancer depiction with CT.¹⁶

One may ask why DCE-CT has not been more extensively used. CT is more readily available at most centers and is used routinely in radiation therapy planning.^{1,5} Successful localization of tumor with DCE-CT would avoid the need for MRI-CT registration for delivering tumor-targeted radiation therapy. In the past, DCE-CT has been difficult to perform in the prostate because of limited coverage with scanners that are only able to cover 2 cm of tissue. This has been remedied by the development of 64 slice and 320 slice scanners that allow for coverage of up to 16 cm of tissue.^{13,17}

Radiation dose and the associated cancer risk remain a concern with DCE-CT compared with MRI, because the latter

involves no ionizing radiation. In particular, typical abdominal CT radiation doses range from 10 to 20 mSV; a single 10 mSV dose is associated with a lifetime developmental risk of 0.1% for a solid cancer or leukemia¹⁸ and a 0.01% to 0.14% lifetime attributable risk of death from cancer.¹⁹ It should be noted that this effect is heavily age dependent: For example, by age 50, the lifetime attributable risk of death from cancer is less than 0.02%.¹⁹

A promising role for DCE-CT may be for prostate cancer localization for improving outcomes in radiation therapy through dose escalation to the dominant tumor focus,^{1,5} because the radiation dose for DCE-CT is relatively minimal compared with a therapeutic dose, and collateral radiation exposure is associated with an increased risk of nonprostatic cancer post-treatment.²⁰

The inherent value of DCE-CT for prostate cancer may lie in its ability to quantify vascular properties of the cancer.¹¹ For each voxel in the image, a curve of contrast enhancement *vs* time can be plotted. This curve can be analyzed using semi-quantitative methods to derive parametric maps, such as peak enhancement, area under the enhancement curve, maximum slope, and washout rate.^{21,22} Alternatively, a pharmacokinetic model based on the assumed contrast kinetics of the tissue microvasculature can be used to derive more physiologic parameters, such as vascular permeability, blood volume (BV), and blood flow (BF) (Fig. 2).⁹

While both DCE-CT and DCE-MRI may be used to determine functional parameters, such as BF, BV, mean transit

FIG. 1. Dynamic contrast-enhanced (DCE)-CT Dynamic CT images were acquired at 0.5-second intervals after injection of intravenous contrast. Graph shows change in attenuation from baseline for the cancer region of interest (white outline) and normal peripheral zone. The image is a single slice at 13 seconds after onset of contrast enhancement (vertical dotted line) in the prostate. Note how the tumor (Gleason 4 + 3) enhances earlier and has a higher peak enhancement than the normal peripheral zone. Benign transition zone nodules (central bright regions) can also exhibit enhancement patterns similar to those of cancer, making diagnosis of cancers in this region difficult. Source: DCE-CT data for this case courtesy of C. Miller, T. Wong, T.J. Polascik, and V Mouraviev, Duke University Medical Center, Durham, NC.

FIG. 2. Right apex Gleason 7 (4 + 3) cancer seen with pharmacokinetic analysis of dynamic contrast-enhanced (DCE)-CT using the images from the case shown in Fig. 1; parametric images of the microvasculature-related parameters (bottom row) were generated on a voxel by voxel basis using CT Perfusion 4 software (GE Healthcare, Waukesha, WI). DCE-CT image through the prostate apex shows a focal region of cancer (white arrows) exhibiting elevated blood flow, permeability surface area product, and blood volume compared with normal peripheral zone. The transition zone nodules can behave like cancers exhibiting increased blood flow and permeability. Source: DCE-CT data for this case courtesy of C. Miller, T. Wong, T.J. Polascik, and V Mouraviev, Duke University Medical Center, Durham, NC.

times (MTT), and permeability surface area product (PS), there are distinct advantages and disadvantages to each of the two modalities when it comes to pharmacokinetic modeling.^{9–11} In particular, analysis of DCE-CT data is significantly easier, because a direct linear relationship exists between the enhancement observed (measured in HU) and the concentration of contrast material injected, which allows for the exact quantification of the arterial input function.^{9,23} In contrast, the MRI signal change not only varies nonlinearly with the contrast dose but also varies with intrinsic relaxation rates, tissue inhomogeneities, and even the pulse sequence used.⁹ DCE-CT suffers from a relatively poorer signal-to-noise ratio, however, compared with DCE-MRI, which may limit detection of small cancers.^{9,11,23}

The use of DCE-CT to measure parameters of angiogenesis has shown validation with diverse paradigms, including the microsphere method ($r = 0.84–0.96$),^{24,25} $H_2^{15}O$ PET ($r = 0.72$),²⁶ and measurements of vascular endothelial growth factor level.²⁷ DCE-CT-measured BF also shows moderate correlation with histologic measurements of microvascular density ($r = 0.44–0.62$)²⁸ and of calculated PO_2 in tumors ($r = 0.47$).²⁹

The evidence for DCE-CT reproducibility and repeatability has been mixed, and both tissue type and the method of analysis may influence these factors; in addition, studies have not been performed for DCE-CT use in the prostate.²⁷ Studies in other organs have suggested interscan variations of 13% to 33% and values for within-subject coefficients of variation ranging from 12% to 47%.^{23,30} Correlation coefficients (Pearson r) for interobserver reproducibility in similar studies are high (0.80–0.94), and a study comparing two analysis methods (slope and deconvolution) showed values ranging from $r = 0.86–0.90$, suggesting that there is good intertechnique validity as well.²³

There are limited studies in the use of DCE-CT in the prostate. A preliminary study by Prando and Wallace¹⁶

showed a simple single time point helical CT obtained 50 seconds after a contrast injection can depict larger and more vascular cancers with an accuracy of 58%.¹⁶ This is fairly similar to transrectal ultrasonography (accuracies of 50%–63%),^{31,32} so a single time point scan is likely inadequate for adoption for planning of focal therapies. Henderson and colleagues²² used the adiabatic approximation of the tissue homogeneity model (modeling tracer kinetics) using high temporal resolution DCE-CT (1 second) to create parametric maps of the prostate allowing for calculations of normal prostatic BF (0.18 ± 0.05 mL/min/g), PS (0.17 ± 0.06 mL/min/g), MTT (49 ± 8 seconds), and BV (0.09 ± 0.02 mL/g).³³ These were significantly different from presumed tumor “hot spots” (BF: 0.37 ± 0.12 mL/min/g, PS: 0.24 ± 0.10 , MTT: 41 ± 16 seconds, and BV: 0.17 ± 0.06 mL/g).

A recent follow-up study by Jeukens and coworkers²¹ used a multislice DCE-CT protocol to image the entire prostate using two scans and similarly analyzed the data using the adiabatic approximation of the tissue homogeneity model. Encouragingly, similar BF calculations were obtained for both normal prostate (0.10–0.17 mL/min/g) and tumorous tissue (0.29–0.45 mL/min/g) in comparison with Henderson’s study.^{21,22} It was shown that at a noise level of ~ 4 HU, one can sufficiently (95% confidence interval) detect a deviation of a parameter from a given threshold using this model.²¹ This noise level can be achieved with a voxel size of 9×9 , which corresponds to a volume of ~ 0.1 mL.²¹ The authors suggest that this is of high enough spatial resolution to detect small and large and irregular-shaped cancers of the prostate.²¹ Whole-mount correlation studies that show the accuracy of DCE-CT for localization of prostate cancer are lacking at present.

Because DCE-CT lends itself to measurements of BF, permeability and BV, it may be a useful tool in the measurement of the radiotherapy response.^{34,35} Harvey and colleagues³⁵ used DCE-CT to measure a number of angiogenic factors for prostate cancer patients after radiotherapy. The study showed

changes in the prostate evident of increased angiogenesis at 1 to 2 weeks after radiotherapy, including increased prostate perfusion (from 0.122 mL/min/mL to 0.263 mL/min/mL) and increased fractional vascular volume (from 13.7% to 21%), with all parameters remaining elevated at 6 to 12 weeks.³⁵

Localization of Prostate Cancer with PET/CT

PET is a technique in which an image of a molecular process is obtained. For this purpose, a radioactively labeled substance, a radiopharmaceutical, is administered to a patient. The substance will participate in a metabolic or (patho-) physiologic process, and accumulate at the sites at which the process is most active. In PET, the radioisotopes used are characterized by a surplus of positive charge in the nucleus, creating an unstable nucleus. Stability is regained by either capturing an electron (= negative charge) into the nucleus or by emitting the surplus positive charge in the form of a positron. The positron will annihilate with an electron, generating two photons of energy.

The radiation resulting from the annihilation event can be detected with conventional gamma cameras, but now dedicated PET cameras are widely available. The principal difference between conventional cameras and PET cameras is the presence of coincidence electronics. As stated, an annihilation event produces two photons released in opposite directions. This means that when an event is detected in a detector, the other event should be detected within a short time frame in an opposing detector. Based on these principles, modern cameras consist of a large number of detectors with coincidence electronics, spanning an axial length of 15 cm or more. The newest cameras have detector and electronics characteristics such that the time difference between the detection of the two photons can be taken into account to locate the exact position of the annihilation.

These machines, so-called time-of-flight machines, are undoubtedly the future of PET cameras. Together with improved image reconstruction algorithms, the spatial resolution of PET will improve further.^{36,37}

In the past few years, a development occurred that already has had great impact in clinical routine: Dual-modality PET/CT that combines PET and CT scanning. The functional and anatomic information offered by PET/CT is being recognized as crucial in the care of oncology patients. PET and PET/CT are playing an ever-increasing role in the management of oncologic disease. A general tendency in tracer development is the search for more specific tracers, while not losing sensitivity. The drawbacks of such tracers problems in locating the tumor are overcome with the new PET/CT machines. Consequently, the development of these machines itself will form a boost for radiopharmaceutical development.

The most commonly used radiopharmaceutical for PET in oncology is the glucose analog 2-[¹⁸F]fluoro-2-deoxy-D-glucose, also called fluorodeoxyglucose or FDG. FDG is taken up by the cell by glucose transporters (mainly GLUT-1) and phosphorylated to FDG-6-phosphate by the enzyme glucose-6-phosphokinase. Whereas glucose-6-phosphate finds itself on a crossroads of a vast number of metabolic processes, such is not the case with FDG-6-phosphate. Because of the introduction of the fluorine atom, the three-dimensional (3D) structure of the molecule changes after phosphorylation changes in

such a way that FDG-6-phosphate is not a substrate for other enzymes anymore. As a result, the FDG is trapped in the cell, at least on the time frame of a normal PET scan.

Unfortunately, prostate cancer displays little glycolytic activity. The added effect of urinary excretion makes it very difficult to determine uptake of FDG in primary prostate cancer. Even under continuous bladder irrigation, FDG was not able to distinguish between scar tissue, benign prostatic hypertrophy, and prostate carcinoma.^{38–40} Also, for restaging after local treatment, FDG performed poorly.⁴¹

PET tracers with more favorable properties have been developed and studied since. One of the most used tracers in prostate cancer is choline. Choline is one of the components of phosphatidylcholine, which in itself is an essential element of phospholipids in the cell membrane. Cancer is associated with cell proliferation and up-regulation of choline kinase (the enzyme that catalyzes the phosphorylation of choline), providing the rationale for the use of choline in oncologic PET.⁴² To overcome the disadvantage of the short half-life of ¹¹C-choline, several ¹⁸F-labeled analogs such as ¹⁸F-methyl-choline and ¹⁸F-ethyl-choline have been developed. Other tracers, including ¹¹C-acetate and ¹⁸F-fluoro-5 α -dihydrotestosterone, are also studied in prostate cancer, but limited data are available on intraprostatic tumor characterization.

¹¹C-choline was reported first for its uptake in prostate cancer by Hara and coworkers⁴³ in 10 patients with known prostate cancer who underwent both ¹¹C-choline PET and ¹⁸F-FDG. The radioactivity concentration of ¹¹C-choline in prostate cancer and metastatic sites showed a standardized uptake value (SUV) >3 in most cases. The preliminary results were validated by de Jong and associates⁴⁴ in a prospective study in 25 patients with histologically proven prostate cancer and in 5 patients with benign hyperplasia. The benign prostate was visualized with a mean SUV of 2.3 (range 1.3–3.2). The primary tumor could be visualized with a mean SUV of 5.0 (range 2.4–9.5) as a hot spot within the prostate gland. Five patients had proven lymph node metastases after pelvic lymph node dissection: In four of these five patients, uptake of ¹¹C-choline in pelvic lymph nodes with metastases of 5 mm to 3 cm was seen with a mean SUV of 4.7 (range 2.9–9.1). One false positive PET was seen in a lymph node with inflammatory changes. In 19 patients without lymph node metastases, results of ¹¹C-choline PET were negative.

Breeuwsma and colleagues⁴⁵ studied the correlation between the uptake of choline and cell proliferation as assessed by tumor histology and parametric influx constant (Ki)-67 expression. This study showed no significant correlation between ¹¹C-choline uptake and Ki-67 staining. No statically significant relationships were found between the uptake of ¹¹C-choline (SUV) and either preoperative PSA or Gleason sum score. Sutinen and coworkers⁴⁶ evaluated the kinetics of the uptake of ¹¹C-choline in prostate cancer and benign prostatic hyperplasia. The value of ¹¹C-choline PET in assessing the malignant potential of prostate tumors was analyzed by correlating tracer uptake with tumor grade, Gleason score, volume of the prostate, and PSA. Fourteen patients with histologically confirmed prostate cancer and five patients with benign prostatic hyperplasia were studied with ¹¹C-choline PET. The mean Ki of untreated prostate carcinoma was $0.205 \pm 0.089 \text{ min}^{-1}$ (range 0.128–0.351, including both primaries and metastases), and the mean SUV was 5.6 ± 3.2

(range 1.9–15.5). There was a close correlation between the ^{11}C -choline influx constant and the SUV of tumors ($r=0.964$, $P=0.0005$; $n=7$). The mean SUV of benign prostate tissue was 3.5 ± 1.0 (range 2.0–4.5; $n=4$), and the mean Ki of the benign prostate in two patients with metabolite-corrected measurement of plasma activity was $0.119 \pm 0.076 \text{ min}^{-1}$ (range 0.065–0.173). The difference between the SUVs of the prostate cancer and benign prostatic hyperplasia was not statistically significant ($P=0.067$). The dynamic curve of ^{11}C -choline uptake showed no apparent difference in pattern between patients with cancerous or hyperplastic tissue.

^{11}C -choline-PET/CT was studied for the detection and localization of tumors within the prostate by Farsad and associates.⁴⁷ PET/CT findings were correlated with histopathologic analysis of the prostate using a sextant biopsy scheme in 36 patients with prostate cancer and of 5 controls. All patients underwent ^{11}C -choline PET/CT and, subsequently, radical prostatectomy with lymph node dissection. Histopathologic analysis identified cancer foci in 143 of 216 sextants biopsied. In addition, high-grade prostate intraepithelial neoplasm (HGPIN) foci were seen in 89 sextants. At least 1 primary prostatic tumor focus could correctly be visualized through PET/CT in a total of 35 of 36 patients.

On a sextant basis, PET/CT demonstrated focal ^{11}C -choline uptake in 108 (50%) sextants: Histologic examination showed that 94 of 108 were affected by tumor, 10 by HGPIN, 2 by HGPIN and acute prostatitis, and 2 by benign prostatic hyperplasia or no pathologic findings. In sextants with areas of abnormal ^{11}C -choline uptake, the mean SUV was 5.3 ± 2.2 (range 2.2–12) and the mean tumor/background (T/B) ratio was 2.0 ± 0.5 (range 1–3.4). PET/CT found 108 sextants without evidence of abnormal ^{11}C -choline uptake. These findings were true negative in 59 of the sextants and false negative in 49; in those 49, histologic examination proved the presence of cancer foci. PET/CT had a sensitivity of 66%, a specificity of 81%, an accuracy of 71%, a positive predictive value of 87%, and a negative predictive value of 55%.

No statistically significant difference was found between tumors and HGPIN using either SUV or T/B ratio. The SUV range measured for cancer foci reflects the heterogeneity of prostate cancer, which could explain the failure to detect all cancer foci. Both conditions (small dimension and low uptake)

could explain the high rate of false-negative results with ^{11}C -choline PET/CT. The study also demonstrated that HGPIN can accumulate ^{11}C -choline. Because HGPIN and carcinoma have a strong tendency to be present simultaneously and exhibit the same “zonal” origin and anatomic proximity, a possible explanation for pathologic uptake of ^{11}C -choline in sextants with HGPIN foci could be that some of these regions harbored a small focus of cancer undetected by pathologists. The complete overlap of SUV and T/B ratio between cancer foci and HGPIN foci detected by PET/CT supported this hypothesis and pointed out that no single SUV or T/B ratio cutoff can differentiate between cancer and HGPIN.

In a clinical study by Martorana and colleagues,⁴⁸ the sensitivity of ^{11}C -choline-PET/CT for intraprostatic localization of primary prostate cancer on a nodule-by-nodule basis was assessed and compared with histology using a 12-core transrectal biopsy scheme and postprostatectomy results. In 43 patients with known prostate cancer who had received ^{11}C -choline PET/CT before initial biopsy, they evaluated sensitivity of ^{11}C -choline-PET/CT for localization of nodules 5 mm or greater using radical prostatectomy histopathology as the reference standard. All 43 patients showed 1 or more focal uptake (total 70); focal uptake was bilateral in 32 (74%) patients and unilateral in 11 (26%). In eight patients, focal uptake was recorded only in the presence of HGPIN.

At nodule assessment, 57/70 instances of focal uptake were in correspondence with the histopathologically identified nodules 5 mm or greater in diameter, corresponding to a sensitivity of 83% for localization of tumor nodules. PET/CT detected only 1 of 23 (4%) cancer focus 5 mm or less.

At sextant results, PET/CT had slightly better sensitivity than transrectal ultrasonography-guided biopsy (66% vs 61%, $P=0.434$) but was less specific (84% vs 97%, $P=0.008$). Testa and coworkers⁴⁹ retrospectively compared sensitivity and specificity of MRI, 3D magnetic resonance (MR) spectroscopy, combined MR imaging and 3D MR spectroscopy, and ^{11}C -choline PET/CT for intraprostatic tumor sextant localization in 26 men with prostate cancer who underwent radical prostatectomy. Sensitivity, specificity, and accuracy of PET/CT were 55%, 86%, and 67%, respectively, vs 54%, 75%, and 61% for MR imaging and 81%, 67%, and 76% for 3D MR spectroscopy. Sensitivity of PET/CT improved using

FIG. 3. ^{11}C -choline PET/CT: (A) focal uptake of choline in a patient with a Gleason 7 (4+3) tumor in the left lobe in all four biopsies and a Gleason 7 (3+4) in 20% of the biopsies in the right lobe; (B) diffuse uptake of choline in a patient with a Gleason 8 (4+4) tumor in the left lobe in all four biopsies and a Gleason 7 (3+4) in all four biopsies in the right lobe.

a quantitative analysis with a maximum SUV threshold of 2.9 or higher. Sensitivity was increased to 72%, reducing specificity to 65%. ¹¹C-choline PET/CT demonstrated a lower sensitivity compared with both 3D MR spectroscopic imaging alone or with combined MRI and 3D MR spectroscopic imaging, with a comparable specificity.

The current literature on intraprostatic localization of recurrent prostate cancer is limited. ¹¹C-choline PET has been shown to be a sensitive technique in localization of the site of recurrence after external beam radiotherapy (either local, regional or distant) in a prospective cohort study by Breeuwsma and coworkers.⁵⁰ The overall concordance of PET with a local recurrence was 88% using a composite reference with histology and clinical follow-up after local salvage treatment. The concordance of the intraprostatic distribution of the tumor with PET with histologic evaluation from serial biopsies was 47% (7/15) in unilateral cases and 41% (11/27) in bilateral cases (Fig. 3.) (Rybalov and associates, unpublished data). This could, in part, be because of sampling errors using sextant biopsies. Whole-mount correlation studies showing the accuracy of ¹¹C-choline PET/CT for intraprostatic localization of recurrent prostate cancer are also lacking at this time.

Future directions of PET/CT imaging is aimed at identifying novel markers that can be used as prostate-cancer-specific targets. In fact, a number of prostate cancer (related) targets, such as prostate-specific membrane antigen, prostate stem cell antigen, gastrin-releasing peptide, and hormone receptors, are already studied in preclinical and early clinical models for their accuracy in imaging primary and recurrent prostate cancer.

Conclusion

Conventional CT and FDG PET are not able to detect prostate cancer foci <5 mm within the prostate. Based on preliminary studies, DCE-CT may be a useful tool for localization of prostate tumors and, perhaps more importantly, quantification of therapeutic response in prostate cancer. Validation work is necessary, however, to define its accuracy and role in therapeutic paradigms, such as focal therapies, particularly given the current accuracy of MRI. In the future, combining DCE-CT with CT or ¹¹C-choline PET/CT may be an alternative to MRI, offering a combination of quantitative parameters that may correlate to tumor prognosis as well as cancer localization for focal therapy.

Disclosure Statement

No competing financial interests exist.

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Abbreviations Used

PET = positron emission tomography
AUA = American Urological Association
BF = blood flow
BV = blood volume
CT = computed tomography
DCE = dynamic contrast-enhanced
FDG = fluorodeoxyglucose
HGPIN = high-grade prostatic intraepithelial neoplasia
HU = Hounsfield units
Ki = parametric influx constant
MR = magnetic resonance
MRI = magnetic resonance imaging
MTT = mean transit time
PET = positron emission tomography
PS = permeability surface area product
PSA = prostate-specific antigen
SUV = standardized uptake value
3D = three-dimensional
T/B = tumor/background