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Prostate MRI for post-treatment evaluation and recurrence

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Synopsis

Prostate mpMRI plays an important role in local evaluation after treatment of prostate cancer. After radical prostatectomy, radiation therapy, and focal therapy, mpMRI can be used to visualize normal post-treatment changes and to diagnose locally recurrent disease. An understanding of the various treatments and expected changes is essential for complete and accurate post-treatment mpMRI interpretation.

Keywords

Prostate cancer; Recurrence; mpMRI; radical prostatectomy; radiation therapy; focal therapy

Introduction

Prostate cancer (PCa) is the most common solid organ malignancy and second most common cause of cancer-related deaths among men in the United States. Last year, approximately 190,000 men were newly diagnosed with PCa and 26,000 men died of this disease¹. Increasingly, timely diagnosis of high grade disease is achieved with use of prostate multiparametric MRI (mpMRI), giving patients with localized disease (Stage I–III) early options for definitive treatment. Treatment commonly includes radical prostatectomy (RP) or radiation therapy (RT), which can include external beam RT (EBRT) or brachytherapy. Generally, RP is preferred for younger men with localized tumors and RT is preferred for elder patients or patients who are not ideal surgery candidates². More recently, patients with a certain pattern of disease visualized on mpMRI may also be offered prostate-sparing focal therapy treatment options which utilize laser technology, microwave ablation, cryotherapy, or high-intensity focused ultrasound (HIFU)^{3,4}. Unfortunately, despite advances in diagnosis and management of PCa, the disease still recurs after definitive treatment in up to 40% of patients⁵. Therefore, detection and treatment of recurrent disease has become a relevant focus across multiple disciplines. From an imaging perspective, prostate mpMRI

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can provide insight not only into primary PCa, but also can achieve good anatomic spatial resolution and provide functional data for visualization of recurrent disease⁶.

After treatment, patients are followed closely for biochemical recurrence (BCR), defined based on serum PSA criteria specific for each treatment option^{7–9}. PSA nadir achieved after each treatment option differs, as in RT and in focal therapy, PSA-producing prostate parenchyma is not completely eradicated⁹. After RP, PSA nadir of undetectable levels is expected, while after RT or focal therapy, a PSA nadir greater than zero is achieved within weeks or months after completion of therapy. Accordingly, in RP patients, recurrence is suspected with an increase in PSA above the threshold 0.2 ng/mL with a second confirmatory level, while in RT patients, an increase in PSA 2.0 ng/mL above the established post-treatment nadir is suspicious¹⁰. PSA patterns are monitored after focal therapy as well, although consensus about kinetics and a threshold value is still being investigated⁹. In patients who receive definitive therapy, BCR indicates locally recurrent disease in up to two-thirds of patients, and this must be extensively evaluated for appropriate subsequent management^{11–13}. Distinction of PSA-producing benign etiologies from local recurrence and distant metastasis is vital. Prostate mpMRI can greatly assist this by aiding visualization of local structures post-treatment, with some considerations^{14–16}. This is clinically very important as localized recurrence that can be visualized on mpMRI can be offered local salvage treatment, which is drastically different from systemic options offered to patients with distant metastatic disease.

Evaluation and imaging of recurrent disease with mpMRI requires certain considerations based on treatment received. Prostate mpMRI's strength lies in combining anatomical data [T1-weighted (T1W) and T2-weighted MRI (T2W)] with functional data [diffusion-weighted imaging (DWI), dynamic contrast-enhanced imaging (DCE)] to provide maximum information about the location and character of possible disease. It is important to note that established guidelines for characterizing and reporting suspicious areas on prostate mpMRI, such as PI-RADSv2, are designed only for characterization of primary cancer¹⁷. While baseline pulse sequences (Table 1) used are the same for post-treatment evaluation, treatment greatly changes anatomy visualized, can change signal intensity on certain sequences, and can introduce artifact that compromises sequence utility. For example, after RP, a drastically different anatomy is visualized on imaging and image artifact may be introduced with use of surgical clips during the procedure. In contrast, after RT, while the general anatomical structures remain the same, the prostate shrinks greatly in size and has different signal pattern on T2W imaging. The purpose of this article is to discuss general guidelines for identifying normal post-treatment changes and possible recurrence on mpMRI, as well as pitfalls of mpMRI interpretation after the various treatments for PCa.

mpMRI following Radical Prostatectomy

RP is a very common active treatment chosen for prostate cancer patients with localized disease, with around 40% of patients undergoing definitive therapy choosing this option¹⁸. RP includes total removal of the prostate and seminal vesicles, along with pelvic lymph node dissection to varying extents for evaluation of local metastasis¹⁹. Subsequent pathology analysis evaluates surgical margins and lymph nodes for staging. Risk for future BCR is a

consideration at this point, as certain characteristics of the original PCa can increase risk of recurrence, such as seminal vesical invasion, positive surgical margins, extraprostatic extension, perineural invasion, lymphovascular invasion, and increased tumor volume¹⁸. After successful surgery, PSA should drop to undetectable levels within 2–3 weeks and patients should be followed with serial serum PSA measurements for early detection of possible BCR. According to the AUA guidelines, BCR after RP is defined as a serum PSA measurement ≥ 0.2 ng/mL, followed by a second confirmatory serum PSA measurement ≥ 0.2 ng/mL⁷. Post-RP, approximately 35% of patients will experience BCR within 10 years, and there are certain parameters that make this recurrence more likely to be found as localized disease^{20–24}. These include PSA increase more than 3 years post-RP, PSA doubling time greater than 11 months, original Gleason score ≥ 7 , and stage $\geq$ pT3a pN0, pTx with negative surgical margins. In contrast, systemic disease can be predicted if PSA increases in less than 1 year post-RP, PSA doubling time is in 4–6 months, original Gleason score was 8–10, and stage $\geq$ pT3b, pTxpN1¹⁰. Imaging can aid with distinguishing between local and distant metastatic disease, and if local disease seems likely, mpMRI specifically can play an important subsequent role in evaluation.

After surgery, the male pelvic anatomy is greatly changed, and this is an important consideration when evaluating the area with imaging. Use of mpMRI is ideal for evaluation of the post-surgical bed, as its functional components allow the important differentiation between recurrent cancer, residual prostate tissue, inflammatory tissue, and fibrosis. Presurgical anatomy is relatively consistent between patients—going superior to inferiorly, the bladder neck lies above the prostate base, seminal vesicles appear between the prostate base and bladder neck, and then the prostate is clearly visualized base to apex. Post-surgical anatomy on mpMRI is drastically different due to the open prostatectomy fossa left behind from where the prostate is removed. Imaging should show the bladder neck descended into the prostatectomy fossa with a more conical shape, the vesicourethral anastomosis (VUA) inferior to the bladder neck, and the retrovesical bed posterior to these structures on the sagittal view. Fat stranding may be present around the bladder base on anatomical imaging. In addition to changed anatomy, there are certain expected post-RP signal patterns and artifacts to consider. The VUA should be visualized as a ring of postoperative fibrosis, exhibiting low signal intensity on all sequences of mpMRI. In certain situations, such as if there was extensive hemorrhage at the time of surgery or if there is inflammatory tissue postoperatively, some VUA hyperintense tissue may be seen on T2W imaging. These circumstances will be discussed more extensively with other recurrent PCa mimics later in this section. It is also important to note that patterns of fibrosis may differ between patients, based on surgical approach used²⁵. If metallic clips were utilized in the surgery, these can be seen as hyperintense structures on T2W imaging. In up to 20% of cases, seminal vesicles may be left behind in the body, and these can be seen in their pre-surgical location with their characteristic tubular structure on T1W or T2W anatomical imaging²⁶. They appear as intermediate to high intensity on T2W imaging, may show restricted diffusion on DWI, and often show early enhancement on DCE^{27,28} (Figure 1). On post-operative imaging of the wider pelvic field of view, it is possible to be able to see lymphoceles in patients who undergo pelvic lymph node dissection. These form due to the accumulation of lymph from damage to the lymphatic system in the resection²⁹. These are visualized at the locations of

former lymph nodes as hyperintense thin-walled cyst-like structures on T2W imaging, and exhibit no enhancement on DCE.

The individual mpMRI sequences vary in utility for post-RP imaging, especially for detection of recurrence. T2W imaging is always used in evaluation post-surgery for anatomy orientation and evaluation of signal patterns. Generally, DWI utility is highly dependent on whether or not surgical clips were used in the surgery. If clips were used, their metallic property introduces susceptibility artifacts to the DWI images, greatly reducing the value of DWI in evaluation³⁰. However, if the patient does not have clips in the post-surgical bed, DWI can be very useful for distinguishing tumor from mimicking etiologies such as inflammation or residual benign tissue. Overall, DCE is much more reliable than DWI, and has been proven as the most useful sequence for detecting recurrence. If looking at a normal postoperative DCE MRI sequence, early enhancement should not be seen in the arterial phase, but there should be some general low-level enhancement of the surgical bed during the venous phase. Changes in early enhancement on DCE MRI are very sensitive for being locally recurrent disease³¹.

Locally recurrent PCa in the post-RP patient may occur anywhere in or around the surgical bed, but most commonly occurs at the VUA¹⁹. Recurrence tends to appear nodular and relatively hyperintense in comparison to pelvic muscle signal intensity on T2W imaging³². On DCE, these areas readily enhance during the arterial phase with quick washout during the venous phase³³. This DCE enhancement appears as a focal nodular enhancement that contrasts sharply with the general background low-level venous enhancement at the VUA, and has been proven to be very important in the MRI evaluation. In one study evaluating 46 post-RP BCR patients, Casciani et al. found that addition of DCE to T2W for evaluation increased sensitivity from 48% to 88%, and increased specificity from 52% to 100%³⁴. Cirillo et al. reported similar findings with their cohort of 72 post-RP BCR patients, with a sensitivity of 84.1% (compared to 61.4%) and specificity of 89.3% (compared to 82.1%) when DCE was combined with T2W, compared to T2W only³¹. Finally, if DWI has not been compromised by use of surgical clips, recurrent disease will appear hypointense on the ADC map and hyperintense on high b-value imaging³⁵. Therefore, overall signal patterns are very similar to those of *in situ* primary PCa. However, recurrent disease is more difficult to identify due to the changed anatomy and missing background of normal prostatic tissue. Additionally, unlike in imaging evaluation for primary PCa, DCE serves as the most important sequence in detection.

There are some common mimics and pitfalls that the radiologist should keep in mind when identifying areas suspicious for post-RP recurrent disease. First, there is always a possibility of residual glandular tissue post-surgery, and this will be PSA-producing and may mimic recurrent disease on imaging. Residual glandular tissue may take on a nodular appearance on T2W, resembling PCa. However, the functional data for this area on MR should help differentiate this benign etiology—it should not have any signal abnormality on DWI and should not enhance early in the arterial phase on DCE²⁸. PSA kinetics should also help; PSA doubling time for residual benign tissue should be much longer than for recurrent disease¹⁵. Second, after surgery, it is possible that granulation tissue or hemorrhage are present near the VUA due to the procedure and subsequent natural inflammation. Granulation tissue will

appear hyperintense on T2W imaging, similar to recurrent tumor, and will hyperenhance on an early DCE phase due to hypervascularity. Extensive hemorrhage will also hyperenhance early on DCE. These mimics can be best separated from recurrent disease on DWI, on which they should appear benign with no notable signal abnormalities. Third, the appearance of fibrosis after RP is variable for each patient and may be confused with recurrence. Fibrotic tissue is highly cellular and thus may have restricted diffusion similar to recurrent tumor on DWI sequences³⁶. It is also possible that on T2 alone, it may be difficult to distinguish local recurrence from mimicking fibrosis if it occurs in a nodular formation. However, on T2W and DCE imaging, fibrotic tissue should appear as more hypointense than recurrent tumor with a delayed thin layer of enhancement during the venous phase^{19,37}.

Various studies have been performed testing the utility of mpMRI in detection of recurrence after prostatectomy. In 84 consecutive post-RP BCR-risk patients, Panebianco et al. found that MRI had higher diagnostic accuracy (sensitivity 92%, specificity 75%) than the alternative PET/CT modality (sensitivity 62%, specificity 50%) in detection of local recurrence³⁸. The same group later verified this with other studies, reporting that mpMRI is the most promising technique for post-RP local recurrence detection³⁹. Out of all of the mpMRI sequences, DCE MRI is repeatedly reported as adding exceptional value to detection. In one analysis of 80 post-RP patients, different mpMRI combinations were tested for detection value. The combinations of T2W+DCE and T2W+DWI+DCE had significantly higher detection rates (76.5%–82.4%) than T2W alone or T2W+DWI (detection rates 25–29.4%)⁴⁰. This incremental value of DCE is verified in a separate study conducted by Wassberg et al., which showed that detection increases along with inter-reader agreement (58% from 39% agreement) with use of DCE MRI⁴¹. In a different study with 262 high risk post-RP patients conducted by Panebianco et al., T2W+DCE gave high sensitivity, specificity, and accuracy (98%, 94%, 93%, respectively). In addition, they found that when DWI is able to be utilized, it can produce comparable detection in combination with T2W (93% sensitivity, 89% specificity, 88% accuracy)²⁸. However, there is no true consensus on the value of DWI, with other studies reporting T2W+DWI sensitivity as low as 46–49%³⁰.

In summary, post-RP, there are many considerations when performing local imaging with mpMRI including changed anatomy, new signal patterns, and abnormalities indicative of recurrent disease. DCE MRI provides significantly more value in detection of recurrent disease compared to primary tumors, and optimal imaging may be achieved with use of all three sequences. Caution should be taken, with the radiologist remaining vigilant for disease that is difficult to identify against a reduced prostate background while also keeping common mimics and pitfalls in mind.

mpMRI following Radiation Therapy

The second most common definitive treatment chosen for Stage I–III PCa is RT, given to up to 40% of patients over 65 years old and up to 25% of patients under 65 years old⁴². RT can be offered as EBRT or brachytherapy. EBRT is generally used for earlier stage disease, and may be offered in forms such as intensity modulated radiation therapy or stereotactic body radiation therapy. In this approach, all radiation is delivered externally and focused through beams to the prostate. In contrast, brachytherapy uses radioactive pellets that are implanted

into the prostate. The seeds internally give off radiation to treat the prostate, and this is best used for low-grade disease and in smaller prostates. For higher-grade disease, brachytherapy may be combined with EBRT for improved cancer treatment⁴³. All radiation therapy may be combined with hormonal therapy in an effort to shrink the prostate for maximal treatment efficacy¹¹. The method of radiation delivery and the incorporation of hormones in treatment are important considerations for post-treatment imaging.

After RT, PSA nadir is not achieved as quickly as it is post-RP, and the decrement is more variable. Generally, patients take around 18 months to reach PSA nadir, but may even take up to 3 years^{44–46}. Establishment of PSA nadir may be further complicated by an observed PSA “bounce” that can occur at 9–21 months that lasts for several months, and is eventually followed by PSA decrease to nadir^{46–49}. Once nadir is established, the patient should be followed with serial serum PSA immunoassays. The American Society for Therapeutic Radiology and Oncology (ASTRO) defines post-RP BCR using the Phoenix criteria, defined as two successive measurements showing a rise in serum PSA of at least 2 ng/mL above the nadir⁸. In patients with high-risk disease, up to around 30% can have BCR post-RT, and risk factors include higher initial clinical tumor stage, higher pretreatment Gleason score, and a shorter time interval from the end of radiotherapy until the detection of BCR^{50,51}. After BCR is first detected, median times to distant metastasis and prostate cancer-specific mortality are 5 and 10 years, respectively⁵². Unfortunately, when attempting to determine if BCR initially represents localized or metastatic disease, RT has less established risk factors compared to RP. Generally, it has been shown that faster PSA kinetics are associated with more adverse disease, higher initial clinical tumor stage has a worse BCR prognosis, and if PSA doubles in less than 8 months especially in the first year after treatment, this can be a predictor for metastatic disease¹³. Majority of post-RT recurrences have been shown to be local, with top site of recurrence being the prostate, and therefore evaluation with prostate mpMRI is essential in the follow up of BCR^{52,53}.

If localized disease is present in the RT patient, it most commonly occurs at the site of original tumor. Therefore, a baseline mpMRI study showing the primary tumor site can be very helpful for subsequent post-treatment evaluation³². Expected post-treatment changes of the prostate on imaging are different based on the mode of radiation delivery employed.

mpMRI after EBRT

EBRT causes overall changes in signal intensity and structure of the prostate. The irradiated prostate appears smaller as a result of gland atrophy and differentiation of the zones is made difficult by effacement of the prostatic tissue⁵⁴. The entire prostate appears hypointense on T2W imaging, further complicating differentiation between zones as well as distinction between benign versus tumor tissue⁵⁵. DWI and DCE appearance of the prostate is impacted as well; post-radiation gland fibrosis is less cellular and has diminished vascularity compared to pre-treatment prostate tissue. However, changes on DWI and DCE are not as drastic as on T2W, and the functional sequences are best for detecting locally recurrent disease.

It is important to note that on anatomical T2 imaging, structures surrounding the prostate appear different as well, compared to their pre-treatment appearance. Seminal vesicles

appear shrunken from effects of radiation and all of the muscles appear relatively hyperintense compared to pre-treatment^{55,56}. Bone marrow visualized around the pelvis will be hypointense on T2W imaging, as a result of fatty replacement of the bone marrow from the effect of radiation.

Identification of post-EBRT local recurrence is made difficult by the glandular changes that occur from treatment. On T2W imaging, recurrence appears as a nodular structure that often exhibits a capsular bulge. The nodular structure is relatively hypointense compared to normal prostatic tissue, and may appear as a bulge due to the rapid growth of tumor relative to the atrophic gland³⁵. Recurrence most commonly appears at the original site of the primary tumor, with only 4–9% of local recurrent disease appearing elsewhere^{57,58}. Unfortunately, due to the changed background signal within the prostate, T2W imaging has marked limitations and is not most important for post-treatment evaluation or recurrence detection. In one study with 64 patients with post-EBRT recurrence suspicion, Westphalen et al. found an area under the curve (AUC) of only 67% in correct detection of recurrent disease on T2 alone.⁵⁹ This was verified by another study, conducted by Sala et al., analyzing a cohort of 45 patients with BCR post-EBRT. They found that sensitivity for T2W alone ranged from 36% to 75%, and specificity ranged from 65% to 81%⁶⁰. As T2W seems to be limited as an independent sequence, the functional sequences of mpMRI play a more dominant role in detection of post-RT recurrence. On DWI, signal characteristics of post-RT recurrence are very similar to characteristics of primary PCa, with a focal hypointensity on the ADC map and hyperintensity on high b-value imaging corresponding with a nodular area visualized on T2W imaging. Studies analyzing the utility of DWI combined with T2W compared to T2W alone show great promise for the utility of DWI in post-RT imaging. In one study of a cohort of 36 patients with post-RT BCR, T2W+DWI achieved significantly higher AUC compared to T2W alone, at 88% versus 61%⁶¹. In another study analyzing 16 post-EBRT patients, Hara et al. found that patient-based sensitivity and specificity for DWI were 100%, with region-based accuracy of 89%⁶². DCE has been proven to be very important in post-EBRT evaluation as well. Although the vascularity of the overall irradiated prostate decreases with gland atrophy, recurrent tumors will retain their highly vascular network^{63,64}. Recurrence will show early hyperenhancement on DCE MRI relative to the treated prostate, and this is especially powerful if it can be correlated with abnormality on T2 or DWI⁶⁵ (Figure 2). In one study of 33 post-EBRT patients conducted by Haider et al., significantly higher sensitivity (72% vs. 38%), positive predictive value (49% vs. 24%), negative predictive value (95% vs. 88%) were found for DCE compared to T2W imaging⁶⁶. Finally, Kim et al. tested utility of both functional sequences, and found that DWI and DCE are both very important for detection of recurrent disease. In their cohort of 24 patients, DWI +DCE was able to achieve significantly higher AUC (86%) than T2W, DWI, or DCE alone ($p<0.05$)⁶⁷.

mpMRI after Brachytherapy

Post-treatment changes to the prostate gland are very similar in brachytherapy to EBRT, however with the addition of visualization of the radioactive seeds used. Brachytherapy seeds are radioactive material contained in small non-radioactive metallic capsules. These metallic capsules introduce MR susceptibility artifacts, which can distort DWI the most and

make interpretation difficult. On T2W imaging, the brachytherapy seeds appear as small hypointense ellipsoid structures scattered throughout the prostate gland. The gland itself is relatively hypointense compared to pre-treatment imaging, and just as seen in post-EBRT imaging, zonal and tissue differentiation are made difficult by the signal change. As a patient completes their brachytherapy course, the prostate gland becomes progressively more atrophic and the seeds gradually migrate peripherally within the gland as it shrinks in size.

Fortunately, recurrence is less of a concern after brachytherapy than it is after EBRT, due to majority of the patients having very low-risk primary disease. If BCR is detected and local recurrence is present, the recurrence will appear as a hypointense nodule on T2W imaging that shows rapid hyperenhancement on DCE MRI. If DWI is not too limited, recurrent tumor will appear hypointense on the ADC map and hyperintense on high b-value imaging. Just as with EBRT, T2W interpretation should be performed with caution, due to the changed glandular background. The general signal properties remain the same between EBRT and brachytherapy, however less studies have been performed to support the use of mpMRI post-brachytherapy, likely because BCR rates are so low. It is suggested that DCE is more important post-brachytherapy than it is post-EBRT due to the seed artifact on DWI³⁷. However, similar to EBRT, the most common site of recurrence post-brachytherapy is at the location of the original tumor.

Thus far, the traditional low dose rate (LDR) brachytherapy has been described, but a new form of brachytherapy is offered in temporary high dose rate (HDR) form. The advantage of HDR is that the source dwell time and position can be modulated, allowing more exact dosimetry⁶⁸. Post-brachytherapy imaging differs with HDR, as the seeds are removed and so the quality does not suffer from susceptibility artifacts. Because HDR is so new and BCR post-brachytherapy occurs less frequently, data validating the use of mpMRI post-HDR is limited. In a study of 16 HDR patients conducted by Tamada et al., DWI shows high sensitivity for detection of recurrence and remains non-compromised with the removal of seeds, and DCE shows early hyperenhancement in recurrent disease. T2W sensitivity is limited due to the limitation of gland background⁶⁹ (Figure 3).

Many of the pitfalls encountered when performing post-RT imaging overlap with usual pitfalls encountered in mpMRI evaluation for primary tumor detection⁷⁰. False positives seen on the mpMRI sequences often correspond with prostatitis, hemorrhage, dysplasia, or BPH, even in the irradiated prostate⁷¹. However, specific to post-RT imaging, a focal hypointensity on T2 may actually be treated tumor. Mimics like this will be most unclear if there is no pre-treatment imaging available. Finally, it is important to make note of whether the patient received hormonal therapy in conjunction with RT. Hormonal therapy can cause additional changes to the gland which can make interpretation even more difficult. Post-androgen deprivation, the prostate shrinks in size, overall ADC values significantly increase, and gland vascularity decreases^{72,73}.

In summary, post-RT there are various factors to consider in local imaging evaluation. If the patient is post-EBRT, overall gland changes must be accounted for. Similar changes must be accounted for in post-brachytherapy patients, with the addition of imaging artifact from the

brachytherapy seeds used. Generally, the functional sequences of mpMRI remain best for detecting local disease post-RT.

mpMRI following Focal Therapy

Focal therapy is a newly emerging treatment option for patients with localized PCa that falls within a certain criteria that allows the index tumor to be directly targeted. Focal therapy relies on use of various energies for local destruction of cancer cells in the gland, such as microwave, focal laser ablation (FLA), cryotherapy, and HIFU. Regardless of which energy is used, there are numerous post-treatment changes seen on follow-up MRI that are important to consider for success of treatment as well as for evaluation of possible recurrence. After a patient receives focal therapy, a good treatment response is defined as a negative control biopsy, absence of a persistent lesion on post-treatment imaging, and a decrease in PSA of at least 50%⁹. Focal therapy is still greatly in its investigative stages and seems to demonstrate reasonable efficacy. However, it is important to note that PSA is not very reliable in post-focal therapy follow-up as there is preservation of a large amount of prostate tissue postablation and thus no agreement on a definition for biochemical recurrence⁴. The consensus is that postablation PSA surveillance should be judged based on PSA kinetics. Many institutions utilize the Phoenix or ASTRO (increase in three successive PSA measurements) criteria for monitoring BCR after focal therapy, but these were both designed for surveillance of whole-gland disease^{74–78}. Therefore, an integrated approach, incorporating mpMRI for imaging surveillance, has been recommended for post-focal therapy follow-up⁹.

In post-focal therapy follow up, it is important to establish post-treatment changes very soon after the energy is applied to the prostate, and to pay attention to the PSA nadir that is established after treatment. In 2014, attempt at standardization of post-focal therapy follow up was made using the Delphi consensus method, by Muller et al. Right after treatment, it is prudent to establish a baseline with regular follow up: a postablation control biopsy that includes targeting of the treated area should be performed, and follow up should be done with mpMRI for a minimum of 5 years (Figure 4). mpMRI should include the standard sequences T1W, T2W, DWI (ADC map, high b-value >1000), and DCE, optimized at 3-T with endorectal coil⁷⁹. It is also suggested by some that an mpMRI be obtained within 2–7 days after treatment in order to capture early post-treatment findings⁸⁰. Generally, the appearance that focal therapy has on mpMRI can make it difficult to assess for recurrence, as the changes that the therapy induces in the prostatic architecture overlap greatly with tumor appearance³².

Post-treatment appearance of the prostate varies somewhat based on energy utilized in the therapy. Cryotherapy alternates freeze-thaw cycles, producing coagulative necrosis within the prostate gland. The visualized area affected by the cycles is often larger than the actual area of cells killed, and imaging can underestimate true effect of the cryotherapy. The treatment area shows drastically changed architecture and hypointensity on T2⁸¹. HIFU, which uses focused ultrasound for heating, will show similar heterogenous hypointensity on T2 but may also show DCE perfusion at the periphery of the treatment area^{81,82}. Finally, FLA will show the heterogenous T2 hypointensity along with restricted diffusion on DWI⁶.

Generally, all treatments eventually result in atrophy of the treated area, causing decreased T2 signal, lower signal on DWI, and lower perfusion on DCE³⁵ (Figure 5).

Most focal therapy methods do not have very long follow up times reported, but there is some data about recurrent disease in current studies. Post-cryotherapy, 20–40% of treated patients have can have BCR, reported up to 10 years from treatment^{83,84}. For post-HIFU follow up, a 160 patient study conducted by Mearini et al. found that BCR-free rate in 72 months was 70% for low risk disease and 41% for intermediate risk disease⁸⁵. Finally, in a Phase II study of FLA in 27 patients, Eggener et al. found cancer in 10 patients at 12-month follow up, with 27% tumors found in the ablation zone and 73% found outside the ablation zone⁸⁶. Appearance of recurrence itself after all treatments takes on signal properties similar to primary disease. Recurrence may be most difficult to differentiate from normal post-treatment on T2, however, making the functional sequences more important for identification³⁵.

Summary & Conclusions

Prostate mpMRI offers promising potential for visualization of post-treatment changes and for evaluation of local recurrent disease in the context of BCR. Because the mpMRI evaluation is so important in detection of localized recurrence, it is vital that the radiologist be communicative with the multidisciplinary team. The referring urologist, radiation oncologist, or medical oncologist should be aware that the radiologist will be acquiring and interpreting a dedicated MRI for post-treatment follow up and recurrence detection. Therefore, the referring physician should provide all of the information that they can about the patient, including entire PCa history, PSA measurements, past treatments, and any past imaging (Table 2). Referring physicians should also advise their patients that for optimal imaging, they will receive a full mpMRI with endorectal coil, acquired at 3-Tesla with contrast injection.

Radiologists can make an important difference in the care of a post-treatment PCa patient. They should be comfortable not only with interpretation of mpMRI for detection of primary PCa, but also with the evaluation of post-treatment local imaging. Diagnosis and timely treatment of recurrent PCa is vital as care of primary cancer improves and course of disease is followed more closely. In the case of a rising PSA, it is important for any radiologist reading prostate images to be familiar with treatment types, with post-treatment anatomy, with appearance of recurrent disease, and with common pitfalls.

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Key Points

- Multiparametric MRI (mpMRI) can help in evaluation of post-treatment changes after diagnosis and treatment of prostate cancer, as well as for diagnosis of locally recurrent disease.
- After radical prostatectomy, radiation therapy, or focal therapy, there are certain expected changes in the remaining tissue.
- Many of the mpMRI patterns of recurrent disease are similar to those of primary prostate cancer. However, in diagnosis of recurrence, normal post-treatment changes and possible inflammation must remain considerations in the interpretation of imaging findings.

Figure 1.

68 year old male, status post radical prostatectomy 5 years prior, presenting with PSA = 0.47 ng/mL for multiparametric MRI evaluation. Axial T2W MRI (A), ADC map (B), b -2000 DW MRI (C), DCE MRI (D) recurrent lesion (arrows). The area suspicious for recurrence appears at the VUA, relatively hyperintense on T2W, corresponding with a hypointense area on the ADC map, hyperintense area on b -2000, and early hyperenhancement on DCE MRI.

Figure 2.

55 year old male, status post external beam radiation therapy, presenting with pre-treatment PSA = 7.96 ng/mL. Axial T2W (A), ADC map (B), *b*-2000 DW MRI (C), DCE MRI (D) show original prostate volume 23 cc and the original tumor in the left mid anterior transition zone (arrows). On 1 year post-treatment follow up, patient presented with PSA = 0.76 ng/mL. Post-treatment axial T2W MRI (E), ADC map (F), *b*-2000 DW MRI (G), DCE MRI (H) show the prostate decreased in size with volume cc and overall gland intensity changes. The tumor (arrows) is smaller and appears less concerning with indistinct DWI signal intensity and no focal enhancement on DCE MRI.

Figure 3.

77 year old male, status post LDR brachytherapy 8 years ago for Gleason 4+4 prostate cancer, presenting with PSA = 11.97 ng/mL. He underwent endorectal coil 3-Tesla MRI after treatment, and then 8 years later for recurrence suspicion. Axial T2W image shows normal post-treatment changes of the gland, with brachytherapy seeds visible as hypointense structures and the background of the gland hypointense with zonal differentiation made difficult (A). Axial T2W (B), ADC map (C), $b=2000$ DW MRI (D), DCE MRI (E) at distal apex of the prostate shows the recurrent lesion (arrows).

Figure 4.

74 year old male, initially presenting with PSA = 7.33 ng/mL. Axial T2W (A), ADC map (B), and DCE MRI (C) show the site of original tumor in the left mid anterior transition zone (arrows), found to be positive for Gleason 3+4 prostate cancer on targeted biopsy. The patient was offered focal laser ablation, and 1 day post-treatment axial T2W (D) shows a hypointensity around the treated area (arrows) with some focal changes in prostatic architecture, ADC map (E) shows corresponding restricted diffusion in the treated area (arrows), and DCE MRI (F) shows low perfusion of this region (arrows). On follow up 1 year later, patient presented with PSA = 2.59 ng/mL and axial T2W (G), ADC map (H), and DCE MRI (I) show shrinkage of the original tumor area with less distinct findings on all sequences. Targeted biopsy of the treated area was negative for disease. At 2 year post-treatment follow up, patient presented with PSA = 5.58 ng/mL with axial T2W (J), ADC map (K), DCE MRI (L) showing overall slightly changed architecture in the left mid anterior transition zone compared to baseline, but no signal findings indicative of disease. 2 year follow-up targeted biopsy of the treated area was negative for disease.

Figure 5.

62 year old male, status post LDR brachytherapy presenting with PSA = 1.98 ng/mL. Axial T2W (A), ADC map (B), b=2000 DW MRI (C), DCE MRI (D) show recurrent lesion in the midline anterior transition zone (arrows). This area was subsequently biopsied and came back positive for prostate cancer. After diagnosis of post-brachytherapy focal recurrence, patient was offered focal laser ablation. The 1-day post ablation DWI image is shown in (E), with the treatment area (dotted arrows) shrinking in size 1 year post-ablation as shown in (F). Post-ablation, biopsy of the area was benign, and PSA = 0.21 ng/mL.

Table 1

Pulse sequences used for post-treatment evaluation with multiparametric MRI.

Multi-parametric MRI Protocol in Recurrent Prostate Cancer Workup
Tri-plane T2W MRI
Diffusion weighted MRI <ul style="list-style-type: none">- ADC map- High b value DW MRI (>1400) (acquired or calculated)
DCE MRI
Pelvic T1W MRI

Table 2

What the referring physician needs to know for local imaging evaluation after treatment of prostate cancer.

What the Referring Physician Needs to Know	
•	This is a dedicated high-resolution MRI for post-treatment follow up
	Essential to provide:
	- Complete prostate cancer history
	- PSA measurements
	- All past treatments
	- Any past imaging