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Future Perspectives and Challenges of Prostate MRI

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Introduction

Prostate cancer is a major cause of morbidity and mortality worldwide [1]. However, unlike other more aggressive cancers, such as lung and pancreatic cancer which are almost always aggressive, prostate cancers exhibit a broad range of biology ranging from indolent to highly aggressive. The term “clinically significant” prostate cancer has recently been introduced to distinguish those tumors likely to lead to death from those likely to be indolent which have no impact on survival [2, 3]. However, the line of demarcation between these two categories of prostate cancer remains unclear and in any given patient can vary.

As a result of this categorization of prostate cancer, management can range from active surveillance to aggressive multimodal radical surgical and radiative therapies. The essential challenge for men diagnosed with prostate cancer is to accurately establish where in this broad spectrum of disease their tumor lies and what its likely trajectory is. This trajectory, which often spans 10–20 years, may well overlap and be superceded by the trajectories of other health conditions the patient may have [4]. For instance, in a 75 year old man with severe cardiovascular disease and hypertension in whom a new intermediate risk prostate cancer is discovered, the former disease is more likely to be a cause of death than the latter and therefore, treatment of the prostate cancer, might not be warranted.

It would be comforting if we could foresee exactly what would happen to a patient in the future were their prostate lesions go undetected or, if detected, untreated. That problem will remain a future challenge for the diagnosis of prostate cancer. However, there is inherent uncertainty over the true aggressiveness of all cancers and new technologies are needed to address this problem. Part of the uncertainty arises simply from sampling issues. For instance, a biopsy may miss a lesion or under-sample a lesion [5]. Therefore, more accurate biopsies will ameliorate part of the problem. But the problems go well beyond that. The lesion itself can be interpreted differently by different pathologists using standard Gleason Scoring [6–8]. Even establishing the correct interpretation, the prediction of patient outcome is not yet satisfactory. Thus, while the concept of tumor aggressiveness is conceptually clear,

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the reality of establishing it is more difficult. Nonetheless, given the multifocality of prostate cancer and the heterogeneity of tumor type within any given tumor, accurate tissue sampling is a fundamental limitation in establishing the aggressiveness of a cancer [9].

Over the past 50 years there have been several major developments in the assessment of prostate cancer. The most important was the development of the Gleason scoring system by Dr. Donald Gleason in the 1960s. Dr. Gleason established 5 patterns of prostate cancer. He suggested that prostate cancers be scored by adding the two major histologic patterns together. Gradually, Gleason pattern 1 and 2 were recognized as benign features with no clinical impact and therefore, are almost never employed in Gleason scoring today. Thus, the original Gleason scoring scale which encompassed scores between 2–10 has been reduced to a scale of 6–10 in current usage. A Gleason score of 6 represents pattern 3+3, whereas a Gleason score of 7 can represent either a 3+4 or a 4+3 tumor [10]. The amount of pattern 4 in a specimen is associated with likelihood of recurrence after treatment which serves as an imperfect surrogate of aggressiveness. The vast majority of Gleason 6 and some Gleason 3+4 tumors are low grade and are rarely associated with disease specific mortality. Thus, except for large volume, low grade prostate cancer most patients with Gleason 6 tumors are recommended to follow active surveillance [11-13]. Intermediate risk cancers are those containing some degree of Gleason pattern 4, the higher the 4 component, generally the worse the outcome. This is a large group of patients and encompasses the full range of biologic aggressiveness. Many men with these Gleason 7 (3+4, 4+3) are probably overtreated. However, aside from Gleason scoring there is no generally accepted good prognostic biomarker for these cancers. Multiple revisions of the Gleason scoring system have tended to increase the Gleason 3+4 category at the expense of Gleason 6 tumors. However, this has the undesirable effect of causing more cancers to be treated because of the increased risk associated with pattern 4. Cancers with higher Gleason scores (Gleason score 8) are considered high risk and have a reasonable expectation of aggressiveness and mortality if untreated. The most recent innovation in pathologic assessment involving the Gleason scoring system is the International Society of Urogenital Pathology's (ISUP) system which is a 1–5 score (whereby Gleason 3+3 is the equivalent of a ISUP 1, Gleason 3+4 equivalent of ISUP2 and so forth) has largely been a rebranding of the existing system [2, 14]. Thus, Gleason or its equivalent ISUP score, despite multiple limitations, remains the pre-eminent method of assessing the aggressiveness of prostate cancer. Numerous methods of assessing genomics of tumors ranging from whole genome sequencing to select subsets of genes have been introduced to help characterize the aggressiveness of prostate cancers. However, none of these has proven superior to the others and only a minority of patients undergo this test. Moreover, the interpretation of the scores of these gene tests is entirely subjective. Thus, better methods of characterizing prostate cancer aggressiveness are needed.

The second big innovation in prostate cancer management was the introduction of the prostate specific antigen (PSA) serum test which was introduced in the late 1980s [15, 16]. The introduction of PSA as a serum test led to an explosion of diagnoses of prostate cancer. Initially, PSA testing was very popular and led to popular screening campaigns. Unfortunately, because PSA is secreted by both normal, hyperplastic and malignant tissue it tends to have many false positives especially in men with benign prostatic hyperplasia or inflammation. When a patient has an elevated PSA level they are commonly recommended

to have a random biopsy (also known as the systematic biopsy or 12 core biopsy). The combination of PSA and random biopsy led to a rapid increase in the diagnosis of prostate cancer, but mostly low risk, indolent cancers. Because Gleason 6 disease was not understood to be as indolent in the 1990s as it is understood today, these patients were often treated with radical surgery or radiation with resultant loss in quality of life (QOL) indices. A series of trials from the US and Europe in the 2000s explored the value of PSA. They generally showed a mild decrease in mortality in subjects undergoing PSA screening but this was only achieved at the cost of significant declines in QOL.

Cumulatively, these studies seemed to indicate that the minimal mortality benefit was canceled out by the decline in QOL [17, 18]. Even before the decision of the United States Preventive Services Task Force (USPTF) in 2012 to recommend against screening with PSA, there was a growing disenchantment with PSA screening. In 2012 when the USPTF discouraged the use of PSA by assigning a letter grade of “D”, there was a further decline in screening [19]. However, reports began emerging after the USPTF decision against PSA screening regarding a rise in the rate of metastatic disease at the time of presentation suggesting declines in PSA screening is leading to more advanced disease at presentation [20-25]. Further criticism of the USPTF decision included the fact that the Prostate Lung Colon Ovary (PLCO) study, the largest study of PSA screening in the US, and one that weighed heavily in the decision to recommend against PSA screening, was flawed because the majority of those in the control arm (no PSA screening) had actually had PSA testing during the study, even though they were reportedly unscreened [26]. This serves to invalidate the results of PLCO trial for prostate screening. In the spring of 2017, the USPTF upgraded PSA testing to a grade of “C” meaning that it should be offered for selected patients depending on individual circumstances and after discussion with the physician [27]. However, the use of PSA screening remains controversial with the majority of urologists considering it worthwhile while the majority of primary care physicians remain dubious of its benefits. There is a major need for a serum or urine test that more accurately identifies patients harboring clinically significant prostate cancers.

Another major development in prostate cancer diagnosis was the introduction of MRI for diagnosis. Throughout the 1990s MRI was principally recommended for staging of prostate cancer, a task for which it proved not particularly well suited. Specifically, the ability to detect extraprostatic extension and local nodal disease are limited with MRI. It was only when MRI began to be used to localize prostate cancer for purposes of diagnosis that its popularity increased [28, 29]. There was a gradual recognition that MRI was capable of detecting lesions that random needle biopsies were missing. This made sense since random biopsies tend to sample mainly the posterior part of the prostate gland; many of the MRI positive lesions were located anteriorly. At first T2W imaging and dynamic contrast enhanced (DCE) MRI were the sequences used to diagnose prostate cancers. Eventually, by the mid 2000s, it became clear that diffusion weighted MRI was the most sensitive pulse sequence for detecting prostate cancer. In the late 2000s the value of high b value MRI was shown (figure 1). Thus, arose the multiparametric MRI or mpMRI that is in wide use today [30].

Of course, it was clear that simply diagnosing a cancer on MRI was not enough, the lesion had to be biopsied. Since the lesion was discovered on MRI it was logical that the lesion be biopsied under MRI. A variety of devices were developed to direct needle biopsies in-gantry using MRI guidance. The patient had to lie prone and the procedure was inherently time consuming because it is difficult to manipulate the needle while the patient is in the center of the magnet. Thus, a series of steps were required, whereby the patient had to be moved in and out of the gantry multiple times while the needle was properly positioned and imaged. This was time consuming for both the radiologist and the scanner both of which added cost. Non magnetic needles and other MRI compatible equipment were needed to safely perform in-gantry biopsies [31, 32]. Importantly, urologists, who were referring patients to radiology practices for such MRI guided biopsies, were not eager to give up the prostate biopsy which was a key element of their practice. Thus, alternatives were sought.

The first alternative was to perform what came to be known as “cognitive fusion” whereby the location of the lesion on MRI was estimated on the transrectal ultrasound (TRUS) image using spatial cues on the image. Since the plane of imaging of the MRI and TRUS are rarely aligned this can be quite challenging and requires operators who are adept at estimating and triangulating locations on scans using internal fiducial markers such as cysts or calcifications [33, 34]. Naturally, there are some operators who are quite good at doing this, but the majority of users find it difficult. It is certainly difficult to teach. Thus, while cognitive fusion has its strong advocates and is very cost effective, it has given way to software/hardware driven solutions, namely the MRI-TRUS fusion biopsy.

The MRI-TRUS fusion biopsy was first described in 2007 by Xu et al [35]. The basic concept was that biopsies could be performed under ultrasound while using MRI for guidance after registration and tracking. The first step was to segment the prostate on MRI. This was initially done manually but is now done in a semi-automated manner on commercial software. When the patient arrives for the biopsy, having previously undergone an MRI, a TRUS is performed in 3D mode. The prostate is segmented on the ultrasound and then it is superimposed on the segmented MRI [36]. This “fusion” was initially done using “rigid” registration but eventually “elastic” registration was implemented, in which the shapes of the prostate on MRI and TRUS were warped to each other so that there was good overlap. Once the MRI and the TRUS segmentations are fused, the TRUS probe must then be tracked so as to maintain the spatial integrity of the MRI superimposed on the ultrasound regardless of the position of the TRUS probe. As the TRUS probe is moved by the user, sensors on the probe or attached to the probe update the fusion image so that the operator constantly sees the updated MRI superimposed on the ultrasound in the same plane. This can be accomplished in a number of ways: radiofrequency tagging of the probe, holding the probe using an articulated arm or by image registration [31]. Regardless, of how the TRUS probe is tracked, needles can then be introduced under real time ultrasound imaging and samples can be obtained from the MRI-defined prostate lesions. This entire process adds 5–10 minutes to a routine TRUS biopsy and with experience can be done very quickly, outside of the MRI suite [31]. The biopsy is generally performed by urologists and as a result it has become widely accepted.

There have been a number of other developments in prostate cancer diagnosis that are too early in development to be considered paradigm shifting and therefore, will not be discussed in detail here. They will be discussed in more detail in the final section regarding the future of prostate MRI. Briefly they include serum or urine tests that help define the risk that the patient harbors a clinically significant prostate cancer. These generally use some combination of kallikrein derivatives or specific RNA markers and are used to define which patient population with elevated PSA should undergo biopsy [37]. They are being introduced slowly into general practice. Another group of new tests are genomic tests of biopsy tissue. These purport to give an added indication of the aggressiveness of the cancer independent or in addition to that of the Gleason score [38]. The full impact of these tests is still unclear as they can add considerable cost to the work up of prostate cancer and it is unclear how the data they produce should be used. For this reason they are not yet playing a major role in diagnosis.

The current status of MRI

Multiparametric MRI (mpMRI) is in relatively wide use today. An enormous boost was received when the 2nd version of the Prostate Imaging-Reporting and Diagnosis System (PI-RADSv2) was introduced in 2015. PI-RADS v2 enabled standardized reporting and provided an important framework for educating radiologists and enhancing communication with urologists. It has been widely adopted by clinicians and imagers alike [30].

The use of prostate mpMRI has been guided by several major studies. Siddiqui et al documented over 1000 cases who had undergone both MRI and MRI-TRUS fusion biopsy and compared this to the results from 12 core biopsies. They found a 30% increase in the rate of detection of clinically significant cancers and a 17% decrease in the rate of detection of indolent cancers. Thus, combined with the unassailable logic that one should see what one is biopsying this study lent credence to the idea that MRI guided biopsies were superior to random 12 core biopsies [39].

The PROMIS trial was a large multicenter trial in which mpMRI followed by targeted biopsy vs. 12 core vs. saturation biopsy (which was the ultimate validation in this study). This study showed that multiple centers could achieve excellent sensitivities for clinically significant cancers but at the same time pointed out that a negative MRI was a strongly positive predictor of the absence of clinically significant cancer. Thus, the authors of this study concluded that MRI could be used as a gatekeeper for biopsy [40]. So far, these recommendations have not been adopted by most practitioners but it shows that PIRADS scoring has evolved from a lesion scoring system for purposes of selecting lesions for biopsy, to the early stages of a prostate cancer biomarker.

MRI has been recommended for patients who have had a prior negative biopsy but continue to exhibit evidence of rising PSA. A joint American Urologic Association (AUA)- Society of Abdominal Radiology (SAR) white paper endorsed the use of MRI in this setting on the premise that the original biopsy may have missed a clinically significant cancer. This is the pre-eminent indication for prostate MRI [41]. Additionally, the role of MRI prior to placing patients on active surveillance is well accepted as 20–30% of AS candidates on purely

clinical grounds are found to have tumors that make them ineligible for AS. Numerous studies have documented this advantage in properly selecting patients for active surveillance [42, 43].

Thus, MRI is now considered an important adjunct in the diagnosis of prostate cancer. A growing number of patients are undergoing MRI prior to their first biopsy but the most common scenarios are that the patient undergoes an MRI for the first time after either a negative systematic biopsy with persistently rising PSA or after receiving a positive biopsy indicating low grade (Gleason 3+3, 3+4 with small amount of pattern 4, ISUP 1 or 2) cancer. In this setting the MRI is used to determine if the patient is truly a candidate for active surveillance. Despite considerable enthusiasm for the use of MRI and MRI-TRUS fusion biopsy and its wide adoption, a number of concerns have been raised as it has become more disseminated. The problems can be divided into those pertaining to the MRI and those pertaining to the biopsy. Among those pertaining to the MRI include the quality of the MRI, the quality of the interpretation and certain inherent limitations of MRI and the current PIRADSv2 scoring system. Among the problems relating to the biopsy include quality of the registration between the MRI and the TRUS and problems relating to the actual performance of the biopsy and its interpretation. Below we detail these issues before concluding with a future look at prostate MRI and image guided biopsy that seeks to address these current issues.

It is clear that the quality of MRI is not uniform across centers. The genesis of non-uniform image quality is complex. It includes the use of outdated equipment but also the improper use of up-to-date equipment. Technical issues such as excessive gas in the rectum can degrade the diffusion weighted sequences rendering the scan difficult to interpret. Inappropriate imaging parameters, particularly suboptimal gradient strength can lead to artifacts that render the images difficult to interpret. Movement and metallic artifacts are additional issues with image quality. Some MRI units perform markedly better with the use of an endorectal coil, however these coils are both expensive and uncomfortable so they are often not used [44-46].

A second factor influencing success is radiologist expertise in interpreting the MRI. Since MRI of the prostate is still relatively new for most radiologists there is heterogeneous experience across centers. This can lead to disappointing local results. Fortunately, there are a plethora of training courses and educational materials that are available for radiologists to improve their skills. The advent of the PIRADS v2 system of scoring creates an easily-taught scale for lesion suspicion that guides clinician with regard to the recommendation for biopsy (figure 2). PIRADSv2 also provides advice on the performance of prostate MRI thereby improving the general outcome. However, there are criticisms of PIRADS v2 particularly its high inter-reader variability and its low predictive value for PIRADS 3 and 4. These pose challenges to the future of MRI of the prostate.

Regardless of image quality and interpretive skills, there are known limitations of MRI. Approximately 5–20% of MRI lesions that harbor clinically significant cancers are either invisible or greatly underestimated by MRI [47-50]. Some centers report false negative rates on MRIs (on a per lesion basis) as high as 30% but more typically this rate is 5–15%. These

arise when clusters of tumors are separated by swatches of normal tissue and thus, the tumor is volume averaged to the point that it is indistinguishable from normal. This means that if MRI alone is used to guide biopsies a significant minority of clinically significant tumors will be missed. Thus, despite the improvement in guidance afforded by imaging, there is still a general recommendation that random biopsies also be included along with targeted biopsies. This commonly results in more biopsy needle passes than before, from an average of 12 to an average of 18 with image guidance (2 biopsies for each MRI lesion, mean number=3). Naturally, this causes more trauma, bleeding and infection opportunities. One hopeful indicator is that completely negative MRIs have a very low risk (<5%) of harboring clinically significant cancers. However, completely negative MRIs are relatively uncommon.

In addition to these false negatives, MRI has a lot of false positives relating to coexisting conditions such as infection, inflammation, prior trauma and hyperplasia. This is especially true in the transition zone (TZ). As a result, even highly suspicious lesions (PIRADS 4 and 5) have a considerable false positive rate. For instance, in a compilation of studies the false positive rate for PIRADS 4 lesions (which are considered high risk) was 60–80% [51]. Thus, many biopsies prove to be negative for cancer and therefore, the patient was put at risk for no benefit. Finally, although MRI directed biopsies reduce the number of low grade (Gleason 6) cancers, MRI does not eliminate them and a moderate number of PIRADS 4 and 5 lesions return as low grade cancers [51].

Concerns have also been raised regarding the biopsy component of the MRI-TRUS biopsy. Segmentations must be accurately performed and their quality must be checked. Importantly, the quality of the fusion between the MRI and TRUS images is especially important at the level of the lesion. This is even more important for smaller lesions where even subtle fusion mismatches can lead to missing the lesion during the biopsy.

Finally, the accuracy of the tracking and patient movement between the image fusion and the actual time of biopsy can cause problems leading to less than ideal results. The accuracy with which the operator directs the needle to the lesion can be another source of error. This is especially true for the platforms that allow freehand motion of the TRUS probe where the user can be significantly off track from the planned biopsy route.

The Future of MRI of the Prostate

Although MRI has introduced a much needed rationality into the diagnosis of prostate cancer there is still room for improvement. It is clear that standards need to be established for what constitutes an MRI of sufficient quality to be used in diagnosis. It is likely that a combination of phantom imaging and analytics of patient prostate imaging will provide quantitative and objective assessments of image quality. Automated systems of image quality assessment would provide a more objective test of sufficient image quality. It is likely that certifications from centralized authorities, will need to be established specifying quality controls needed to perform MRI. The same certification process may also apply to radiologists who wish to interpret prostate MRI. This would follow the history of mammography and MR of the breast that was initially performed by generalists but evolved into a speciality of its own with its own regulatory and quality control processes.

The problems of false positives, false negatives and inter-reader variability may be addressed with computer aided diagnosis (CAD) algorithms. Using machine learning methods, algorithms can be trained to recognize intermediate and high risk cancers [52-54]. When used as an adjunct to a radiologist's interpretation they enable more clinically significant cancers to be detected and fewer low grade tumors. They can be trained against Gleason or ISUP grading, immunohistochemistry and even genomics. As an output they can better predict where clinically significant lesions are likely to be. Early experience with CAD suggests that it leads to more uniform interpretations across readers with lower experience levels and can better predict where the most worrisome part of the tumor is. Currently biopsies are aimed at the geometric center of a lesion; in the future CAD methods may help direct biopsies to the most biologically significant part of the tumor (figure 3). Moreover, because CAD systems can recognize subtle changes in the image not directly visible it tends to more accurately reflect the true extent of the tumor. This is of particular importance for focal therapy wherein if the visible lesion alone is treated, there is 10–30% of local recurrence due to incomplete ablation. Treatment based on CAD findings may result in more complete treatments with lower rates of recurrence. The rate of false negative MRIs should also decrease as CAD algorithms can detect subtle textural abnormalities that are below the detection threshold of the human eye.

The PIRADS system requires revision. Although it has been widely accepted it is variably interpreted owing to the subjective criteria it utilizes [55-57]. One approach might be to rely on more quantitative aspects of MRI including Apparent Diffusion Coefficient, T2 values and kinetic information from DCE MRI. The development of CAD tools has also taught that some features such as lesion heterogeneity, prostate shape, lesion shape and dimensions, currently not standardized as “imaging parameters” may also provide useful quantitative information that could be more reproducible among readers. Further, reducing the high false positive rate of MRI for PIRADS 4 lesions is a desirable goal. More focus on additional criteria suggested here may improve this situation.

A very important development in prostate cancer detection will be improvement in the definition of clinically significant prostate cancer. Current definitions include many cancers that prove to be indolent especially when patient co-morbidities are considered. Thus, a redefinition of clinically significant cancers may have a profound influence on the ability of MRI to detect them. This will inevitably entail less reliance on the Gleason scoring formulation to assess aggressiveness and more reliance on laboratory markers such as immunohistochemistry or genomics. For instance, more aggressive tumors tend to be larger, lower in ADC and T2 value and enhance more readily than less aggressive tumors. On the other hand, while the majority of patients with low risk disease are offered active surveillance many patients who might benefit from AS are treated radically. MRI is very useful in confirming that they are indeed active surveillance candidates. However, a large number of patients are considered intermediate risk including Gleason 3+4 and Gleason 4+3 lesions (ISUP 2 and 3). The majority of these cancers are non lethal, but the presence of grade 4 in the specimen causes sufficient concern that active treatment is often recommended. This is unfortunate as many of those tumors will never progress to metastatic disease. However, the Gleason scoring system, while predictive for low and high risk cancers is not highly predictive for intermediate risk. New genomic tests of biopsy tissue

may serve to divide intermediate patients into intermediate-high risk and intermediate-low risk thus encouraging intervention in the former and surveillance in the latter. The ability to obtain an accurate sample of the tissue is vital for accurate genomics. Thus, multiple samples from different parts of an index lesion may be important in predicting the outcome in a given patient.

The fusion biopsy process itself is also ripe for improvement. The current system relies heavily on the operator to properly register the images and move the biopsy probe. One can easily envision future devices in which the CAD not only segments the prostate MRI and Ultrasound, recognizes the most suspicious lesions but also performs the registration and monitors it continuously. Robotic arms could be used to direct the course of the biopsy needle more accurately into predetermined targets. Accurate mapping of lesions could be performed and could be archived for future use. Alternatively, virtual reality headsets could be used to improve the “cognitive” biopsy by creating virtual overlays of the MRI on the ultrasound in real time and allowing the user to direct the needle into the lesion.

The rise of new positron emission tomography (PET) agents targeted to prostate cancer may usher in a new era wherein both PET and MRI are used to detect and stage cancers. For instance, prostate specific membrane antigen (PSMA) targeted PET probes show remarkable sensitivity for aggressive cancers both within and outside the prostate gland [58-61]. Currently, and for the foreseeable future, PSMA PET imaging will likely be too costly to be used routinely in the diagnosis of prostate cancer except for high risk patients (high PSA and Gleason/ISUP Score) PSMA scans may be used for staging. In this regard the opportunity to either fuse the PSMA scan to the MRI or obtain both scans together in a PET/MRI scanner will provide improved anatomic information (MRI) as well as improved specificity (PET) [62].

Conclusions

MRI has become an important part of prostate cancer diagnosis. As with any new modality that combines unassailable logic with reasonably good data, it has been rapidly adopted. With such rapid growth there are also problems. Once the method is out of the carefully controlled environments of academic centers, great variations in quality and skill become evident and results in general practice are usually not as impressive as they were in academic centers. However, this very observation provides an impetus to improve the method and make it “bullet proof” and thus, more widely available and more broadly robust. Improved quality assurance of MRI scans including a certification process will likely result in better outcomes. The wider use of computer assisted diagnosis and other machine learning techniques promise to bring the inexperienced reader up to the level of an experienced reader while decreasing interreader variability. Improved characterization of clinically significant prostate cancer may assist in making MRI more useful in patient management. Improved methods of registering MRI to TRUS and robotic arms controlling the biopsy should reduce the impact of inexperienced operators and make the entire system of MR guided biopsies more robust. Indeed, the same tools that go into guiding accurate biopsies can also be employed, outside the MR gantry, to direct focal therapies. The possibility of combining PET using prostate-targeting probes such as PSMA directed tracers with MRI portends a

future where the need for biopsy will be reduced and the true extent of the cancer can be more accurately assessed. The future of prostate MRI will build on the current challenges and imperfections to make a more robust and useful tool in the coming decade.

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Figure 1.

55-year old male with serum PSA=30ng/ml with 2 prior negative biopsy. Axial T2W MRI shows a lesion in the anterior transition zone (arrows) (a), which shows restricted diffusion on ADC map (b) and b2000 DW MRI (c) (arrows) and early contrast enhancement on DCE MRI (d) (arrows). The lesion underwent TRUS/MRI fusion guided biopsy which revealed Gleason 4+4 prostate adenocarcinoma.

Figure 2.

59-year-old male with serum PSA= 6ng/ml and no prior biopsy history. Axial T2W MRI shows a lesion in the left mid peripheral zone (arrow) (a), which shows mild diffusion restriction on ADC map (b) and b2000 DW MRI (c) (arrow) and marked early enhancement on DCE MRI (d) (arrow). The lesion underwent TRUS/MRI fusion guided targeted biopsy which revealed Gleason 3+4 prostate adenocarcinoma.

Figure 3. 57-year-old male with serum PSA= 5.87ng/ml and no prior biopsy history. Axial T2W MRI shows a lesion in the left mid peripheral zone (arrow) (a), which shows diffusion restriction on ADC map (b) and b2000 DW MRI (c) (arrows). CAD map derived from mpMRI (overlaid on axial T2W MRI) localizes the suspicious lesion (d) (arrow). The lesion underwent TRUS/MRI fusion guided targeted biopsy which revealed Gleason 4+4 prostate adenocarcinoma.