

A narrative review of biparametric MRI (bpMRI) implementation on screening, detection, and the overall accuracy for prostate cancer

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Abstract: Prostate cancer is the most common malignancy in American men following skin cancer, with approximately one in eight men being diagnosed during their lifetime. Over the past several decades, the treatment of prostate cancer has evolved rapidly, so too has screening. Since the mid-2010s, magnetic resonance imaging (MRI)-guided biopsies or ‘targeted biopsies’ has been a rapidly growing topic of clinical research within the field of urologic oncology. The aim of this publication is to provide a review of biparametric MRI (bpMRI) utilization for the diagnosis of prostate cancer and a comparison to multiparametric MRI (mpMRI). Through single-centered studies and meta-analysis across all identified pertinent published literature, bpMRI is an effective tool for the screening and diagnosis of prostate cancer. When compared with the diagnostic accuracy of mpMRI, bpMRI identifies prostate cancer at comparable rates. In addition, when omitting dynamic contrast-enhanced (DCE) protocol to the MRI, patients incur reduced costs and shorter imaging time while providers can offer more tests to their patient population.

Keywords: bpMRI, biparametric, prostate cancer, diagnostic imaging, specificity and sensitivity

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Introduction

Prostate cancer is the most common malignancy in American men following skin cancer, with approximately one in eight men being diagnosed during their lifetime. In 2021 alone, there are an estimated 248,530 new cases.¹ Furthermore, it has the second highest mortality rate of all cancers afflicting men, killing 1 in 41 patients diagnosed with prostate cancer. Fortunately, since 1993, the American Cancer Society estimated a 52% reduction in mortality, with a steady decline in incidence rates; this drop has been attributed to technological advances in treatment, early diagnostic detection, and prostate-specific antigen (PSA) screening.² The American Urological Association recommends shared decision-making for prostate screening in men between the ages of 55 and 69, with routine screening completed on a 2-year interval.³ After the diagnosis of prostate

cancer has been made, prior to current guidelines low-risk disease (Gleason grade group 1 and PSA level <10 ng/ml) was often treated with radical prostatectomy.⁴ In 2018, National Comprehensive Cancer Network (NCCN) guidelines highlighted that practice has shifted away from surgical intervention and recommended active surveillance for patients with very low to intermediate-favorable risk prostate cancer.⁵

Over the past several decades, the treatment of prostate cancer has evolved rapidly, so too has screening. The first step of prostate cancer screening involves PSA testing. An elevated PSA over 3 warrants further investigation, especially if the patient is experiencing lower urinary tract symptoms, by obtaining a biopsy. Historically, systemic transrectal ultrasound (TRUS)-guided biopsies have been the standard of care method

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for prostate cancer detection after PSA elevation or an abnormal digital rectal exam (DRE).⁶ TRUS-guided biopsies involve 10–14 biopsy needles, depending on the providers' preference also known as cores, inserted through the rectum into the prostate. These biopsies are obtained at various locations throughout the prostate using a template configuration. The major complication of TRUS-guided biopsies are biopsy site infections leading to sepsis, occurring in 2–5% of all men undergoing this procedure.⁷ In response to this complication, transperineal biopsies have had growing utilization within the field, as they have markedly lower rates of subsequent infectious complications.⁸ After pathologic interpretation of Gleason grade, volume of disease, and number of positive cores, men who harbor no cancer are routinely screened using PSA tests and for cause biopsies. For cause biopsies are ideally obtained when a patient experiences an increase in PSA or new/increasing evidence of cancer in the form of an abnormal DRE and/or distant metastasis.

Using template biopsies are, however, prone to false negatives as the template configuration does not allow for characterization of outlying cancers in biopsy-naïve men. The concern for missing clinically significant cancer (Gleason grade group ≥ 2), ever growing numbers of unnecessary biopsies, and overtreatment of low-risk disease have led the need for breakthroughs in biopsy methods. Efforts have been made to utilize an alternative diagnostic pathway that is more accurate in detecting malignancies with reduced harm to the patient. Since the mid-2010s, magnetic resonance imaging (MRI)-guided biopsies or 'targeted biopsies' has been a rapidly growing topic of clinical research within the field of urologic oncology. MRI-targeted biopsies are shown to be non-inferior for the diagnoses of prostate cancer and resulted in lower detection of clinically insignificant cancer when compared with standard template biopsies.^{9,10} This research has paved the way for MRI implementation as the standard of care for biopsy-naïve men and those on active surveillance within the United States. Specifically, biparametric MRI (bpMRI)-targeted biopsies have increased in popularity due to fewer required scan sequences, cost-effectiveness, and accuracy at detecting prostate malignancies when compared with template TRUS biopsies.

While a PSA >3 deserves further investigation, the causes of an elevated PSA are many and include vigorous exercise to malignancy. Risk

calculators are available to physicians that help identify candidates for prostate MRI imaging, who are at increased risk of malignancy. Rotterdam Prostate Cancer Risk Calculators can be used to help inform patients on their risk of prostate cancer at various stages of their cancer workup.¹¹ The first calculator inquires about clinical risk factors of the disease, including family history, age, and protective urinary symptoms. The second calculator then takes PSA into account. These tools assist in informing patients and narrow the number of unnecessary MRIs nationwide, as the false positive rate of using a PSA >3 cutoff for prostate cancer has been stated as high as 75.9% in the literature.¹² In addition, it must be noted that the Rotterdam calculators have limited application for patients of African American heritage. This is because the original study these calculators are based on, enrolled only but a few African American patients.

Technical description of bpMRI and Prostate Imaging Reporting and Data System Score

The aim of this publication is to provide a review of bpMRI utilization for the diagnosis of prostate cancer and a comparison to multiparametric MRI (mpMRI). MRI for the diagnosis of lesions suspicious for prostate cancer goes back to the 1980s. Potential lesions were determined using three planes, with a field strength of 0.08 T.¹³ Steyn and Smith found that an accurate diagnosis of prostatic disease [malignant, benign prostatic hyperplasia (BPH), or normal] was made in 48 of 51 of their patients. However exciting, the MRI employed at the time was still yet a prototype and advances in imaging protocols and biopsy integration were needed. The next major step forward happened in the 1990s with the advent of dynamic contrast-enhanced (DCE) and diffusion-weighted imaging (DWI) MRI protocols. DCE can be explained by the uptake pattern after the administration of an intravenous gadolinium-based contrast agent.¹⁴ An image is obtained before contrast is administered and sequentially repeated at different time intervals after the tissues are introduced to contrast agent, thereby shortening the T1. Magnetic resonance (MR) signal intensity is then analyzed for changes dependent on the specific concentration of dye within the tissue. Signal intensity is a representation of multiple factors including tissue permeability, degree of vascularization, and vascular surface area to name a few. A region of interest (ROI) is identified based on differences in these

factors affecting the MR signal intensity. DWI, on the contrary, is based on cellular Brownian motion after T2-weighted images are obtained.¹⁵ This is uniquely useful for identifying prostatic neoplasms because they are commonly hypercellular, resulting in reduced Brownian motion that can be manipulated as the *b*-value. Two types of MRIs have emerged for the management of prostate cancer, bpMRI and mpMRI. bpMRI uses T2-weighted images with DWI while mpMRI adds DCE with or without spectroscopy to its imaging protocol.

bpMRI results are used to determine the Prostate Imaging Reporting and Data System (PI-RADS) score. In 2012, PI-RADS version 1 (v1) offered radiologists an integrated reporting schematic and standardized protocols across different providers.¹⁶ Through trial and error, flaws within the reporting system were identified and an updated version 2 was published in 2015.¹⁷ This PI-RADS version 2 provided prostate zone-specific scores. T2-weighted images are further delineated based on the ROI's location within the prostate, transitional *versus* peripheral zone. However, an ROI's location is not significant to determine a PI-RADS score based on DWI. In addition, version 2.1 was published around the same time and added a DCE-based score for mpMRIs.¹⁸

Guidelines suggest the use of PI-RADS version 2 for bpMRI images. This score is based on distinct radiologic features.¹⁷ No abnormality seen on apparent diffusion coefficient (ADC) with a high *b*-value is indicative of PI-RADS 1. PI-RADS 2 is a linear/wedge-shaped hypointensity on ADC or hyperintensity on DWI. A focal or marked hypointensity on ADC and/or hyperintensity on DWI is PI-RADS 3. PI-RADS 4 and 5 are focal hypointense regions with hyperintense DWI differentiated based on <1.5 and ≥ 1.5 cm in size, respectively. However, if extraprostatic extension is identified on imaging, PI-RADS 5 is always assigned. An in-depth explanation of radiologic features qualifying for each PI-RADS score can be seen in Table 1, as a score might differ based on the anatomic location of an ROI. These PI-RADS scores help physicians determine whether a biopsy is warranted, as they have been linked to an increased risk of an ROI to be clinically significant cancer. PI-RADS 1 and 2 have very low and unlikely clinical suspicion. While PI-RADS scores 3, 4, and 5 have increasing clinical suspicion noted as intermediate, high, and very high risk of clinically significant prostate

cancer (csPCa), respectively. Unfortunately, there is debate within the literature on which PI-RADS scored ROIs should be biopsied. PI-RADS 1 is routinely interpreted as normal prostatic tissue and rarely, if that, a candidate for biopsy. On the contrary, PI-RADS 4 and 5 have shown to be suspicious for prostate cancer and are routine biopsy candidates. The debate exists on PI-RADS 2 and 3 lesions; variable results on cancer detection rates are present in the literature.

BpMRI accuracy and prostate cancer detection rates

Early studies on prostate biopsies integrated with MRI identification of ROIs, used a technique called cognitive fusion, where the urologist performing the biopsy would approximate the location of an ROI upon reviewing the imaging during the procedure. TRUS MRI-guided biopsies were performed under conscious sedation with an endorectal ultrasound probe positioned to visualize the prostate, where a core would be taken manually. The advent of computer integration of MRI with ultrasound through devices like the UroNav allows physicians to visualize ROIs in real time. However, cognitive fusions have comparable PCa detection rates as MRI/TRUS fusions. In 2015, Rais-Bahrami *et al.*¹⁹ published a cohort of 143 biopsy-naïve patients undergoing mpMRI and analyzed their outcomes when DCE results were omitted. This is considered a 'what if' study because omitting the DCE results explores the utilization of bpMRI in this cohort. bpMRI outperformed PSA and PSA density (PSAD) testing with a prostate cancer detection overall accuracy of 80%. When integrating bpMRI results with PSA and PSAD, the accuracy was further improved. Fascelli *et al.*²⁰ then validated these results in a cohort of 59 men undergoing bpMRI. These researchers found bpMRI had a sensitivity of 95.5% and negative predictive value of 71.4% for prostate cancer.

A 2018 meta-analysis sought to also determine the overall accuracy of bpMRI for the detection of cancer. Niu *et al.*²¹ examined a total of 33 studies examining bpMRI and prostate cancer. Across the selected published literature, the overall bpMRI sensitivity and specificity for all Gleason grade groups were 81% and 77%, respectively. Bass *et al.*²² updated this meta-analysis in 2020, which furthered our

Table 1. Radiological features of each PI-RADS score v2.1.

PI-RADS score (risk of csPCa)	Transitional zone		Peripheral zone	
	T2 W/DWI	DCE	T2 W/DWI	DCE
1 (Very low)	Normal appearing zone or a round completely, well-defined, encapsulated nodule. Heterogeneous intermediate signal intensity (SI)	–	Uniform high signal intensity. No abnormality identified on ADC and high <i>b</i> -value DWI	–
2 (Low)	Mostly encapsulated nodule or homogeneous, well-marginated, circumscribed nodule without encapsulation or homogeneous mildly hypointense area between nodules. Indistinct hypointense on ADC or diffuse hyper-SI on $\geq b = 800$ with no focal features	–	Linear, wedge-shaped, or geographic hypointensities on ADC mapping or hyperintensity at high DWI <i>b</i> -value	–
3 (Intermediate)	Heterogeneous signal intensity with obscured margins; includes other lesions that do not qualify as 1, 2, 4, or 5. Heterogeneous signal intensity with obscured margins. Focal mildly/moderately hypointense on ADC and isointense/mildly hyperintense on high <i>b</i> -value DWI	–	Focal hypointensity on ADC or focal hyperintensity at high DWI <i>b</i> -value not categorized as PI-RAD 1, 2, 4, or 5. Regions can be either focally or markedly intense but not both	No early or contemporaneous enhancement or diffuse multifocal enhancement not corresponding to a focal finding at T2-weighted imaging or focal enhancement corresponding to a lesion demonstrating features of BPH
4 (High)	Lenticular or non-circumscribed, homogeneous, moderately hypointense lesion, that is, <1/5 cm in greatest dimension. Focal markedly hypointense on ADC and markedly hyperintense on high <i>b</i> -value DWI	–	Circumscribed, homogeneous focal markedly hypointense on ADC and markedly hyperintense at high DWI <i>b</i> -value with greatest dimension <1.5 cm	Focal enhancement that occurs earlier than or contemporaneously with enhancement of adjacent normal prostatic tissue with corresponding concerning T2 and DWI findings ^a
5 (Very high)	Same as PI-RADS 4 with greatest dimension ≥ 1.5 cm or evidence of definite extraprostatic extension/invasive behavior. Focal, hyper-SI on the high <i>b</i> -value images with reduced ADC	–	Same as PI-RADS 4 with greatest dimension ≥ 1.5 cm or evidence of definite extraprostatic extension/invasive behavior. Focal, hyper-SI on the high <i>b</i> -value images with reduced ADC	–

ADC, apparent diffusion coefficient; BPH, benign prostatic hyperplasia; DCE, dynamic contrast-enhanced; DWI, diffusion-weighted imaging; PI-RADS, Prostate Imaging Reporting and Data System; ROI, region of interest; csPCa, clinically significant prostate cancer.

PI-RADS score differs based on the anatomic location of an ROI within the prostate. This information was adapted from Barrett *et al.*¹⁷ and Purysko *et al.*¹⁸

^aAny ROI with a T2/DWI score of 3 along with a positive DCE with focal enhancement, outlined above, is categorized as PI-RADS 4 lesion.

understanding by presenting data for clinically significant prostate cancer. Across 44 studies, the sensitivity, specificity, and area under the curve (AUC) of bpMRI for clinically significant prostate cancer were 87%, 72%, and 87%, respectively. Recently, Cuocolo *et al.*²³

undertook their own meta-analysis on 17 studies containing 3964 patients. Within these studies, the odds ratio for bpMRI to detect clinically significant prostate cancer was 12 [95% confidence interval (CI), 8–19] in relation to systematic sampling. These meta-analyses highlight bpMRI

is highly accurate for prostate cancer and clinically significant malignancies.

While accuracy has been identified over all biopsies, there are significant differences in cancer detection rates when taking the PI-RADS v2 score into account. Kuhl *et al.*²⁴ analyzed the cancer rates in 542 men undergoing bpMRI for an elevated PSA. Within their cohort, the distribution of PI-RADS 3-5 *versus* PI-RADS 1-2 lesions were 36.7% and 66.3%, respectively. PI-RADS 3-5 lesions had a true positive, false negative, and false positive rate of 77%, 13%, and 9.5%, respectively. For PI-RADS 1-2 lesions, the cancer detection rate remained low at 6.2%. De Visschere *et al.*²⁵ took this study one step further by evaluating the cancer rates of each specific PI-RADS v2 score. PI-RADS 3, 4, and 5 displayed an increasing stepwise likelihood for prostate cancer with 40%, 78.8%, and 93%, respectively. Nevertheless, these numbers are likely inflated due to an increased average PSA of 9.2 within their cohort. Kato *et al.*²⁶ then found a positive correlation between increasing bpMRI PI-RADS score and Gleason grade. In short, not only are PI-RADS 4/5 ROIs more likely to contain cancer but the neoplasm they harbor also tend to be associated with a poorer prognosis. In addition, an elevated PSA is historically concerning for cancer, but in these cohorts, over 60% of patients were found to have PI-RADS 1 or 2, considered to be very low and low risk for csPCa. These studies highlight that PI-RADS 3-5 are concerning findings on bpMRI because rates of overall and clinically significant cancer increase as the PI-RADS score goes from 3 to 5.

MRI implementation in prostate cancer biopsies has improved the rate of diagnosis and has also shown to be an effective screening tool. Boesen *et al.*²⁷ published their landmark publication that examined if bpMRI was an effective screening tool. This study included 1020 biopsy-naive men with an elevated PSA ≥ 4 ng/ml and/or an abnormal DRE. Over all biopsies, this research identified prostate cancer in 64% of their cohort. Then these researchers filtered each biopsy based on their bpMRI PI-RADS score. For their PI-RADS score 1 and 2 biopsies, clinically significant prostate cancer was diagnosed in 2.6% of these patients. The rates drastically improved for PI-RADS 3, 4, and 5 ROIs, which had clinically significant cancer detection rates of 13%, 39%, and 77%, respectively. Jambor *et al.*²⁸ also sought to evaluate if bpMRI could be used as a screening

tool; 175 men were enrolled into their study who got two targeted biopsies per ROI. In Jambor *et al.*'s cohort, reserving biopsies to men with concerning bpMRI findings resulted in 24% of patients receiving unnecessary biopsies. When bpMRI is implemented as a secondary triage tool for patients with an elevated PSA, this study is a call for physicians to only biopsy ROIs with PI-RADS score of ≥ 3 . Reducing the number of unnecessary biopsies saves the patient from complications but also the cost associated with the procedure. It must also be noted that while PI-RADS 5 is highly likely for cancer, it is not a 1 to 1 ratio for the diagnosis of a prostatic neoplasm. Vice versa is true for PI-RADS 3 ROIs with the risk of high-grade prostate cancer always present, no matter how unlikely. However, biopsing PI-RADS 2 and 3 lesion has diminishing returns, as many of them come back as high-grade prostatic intraepithelial neoplasia, atypical small acinar proliferation, or benign prostatic tissue.

BpMRI versus mpMRI test accuracy

As previously stated, there are two main types of MRIs a physician can order if prostate cancer is suspected. This makes for a precarious decision, as heterogeneous data have been presented within the literature. In 55 patients undergoing mpMRI, Baur *et al.*²⁹ assessed if DCE imaging improved the overall accuracy of an ROI's assigned PI-RADS score to identify a malignancy on biopsy. T2 weighting and DWI alone both had an AUC of 88% and 93%, respectively, with no difference in Receiver Operating Characteristic (ROC) curves between the two methods. DCE alone displayed an AUC of 76% and when compared with T2 weighting and DWI had statistically lower accuracy (p values = 0.06 and 0.004). In addition, the sum of all methods (T2-weighted images, DWI, and DCE) was comparable to T2 weighting and DWI separately alone. While Baur *et al.* showed DCE did not improve diagnostic accuracy across the whole prostate, Rosenkrantz *et al.*³⁰ evaluated the PI-RADS score determined by mpMRI for transitional zone ROIs. A total of 3 radiologists read the same imaging studies of 106 patients (35 with transitional zone lesions) prior to prostatectomy. Across all radiologists, T2-weighted imaging with DWI displayed a significantly higher sensitivity than T2-weighted imaging alone ($p \leq 0.002$). These researchers then assessed if adding DCE to the MRI protocol improved the diagnostic accuracy. Rosenkrantz *et al.* stated, 'Incorporation of DCE-MRI did not

further significantly change the sensitivity for any reader ($p \geq 0.054$).³¹ Radtke *et al.*³¹ expanded our knowledge by further evaluating MRI methods on anterior fibromuscular stromal lesions. They found that MRI-targeted biopsies were able to detect lesions within the anterior prostate at higher rates than standard template biopsies. However, bpMRI and mpMRI displayed comparable detection accuracies. The anterior prostate has debatable importance for patients with African American heritage. Sundi *et al.*³² showed African American men had higher rates of anterior lesions. However, the literature is moving away from this misconception, as Koller *et al.*³³ and Patel *et al.*³⁴ have shown comparable rates of anterior lesions between men of African American heritage and the general population. In 2019, Sherrer *et al.*³⁵ then found, in a cohort of 344 patients, that bpMRI had comparable PCa detection rates to mpMRI with the added benefit of reducing cost, time, and possible complications of contrast exposure.

While several studies have highlighted that bpMRI is comparable to the more expensive mpMRI, there is heterogeneous data published. Delongchamps *et al.*³⁶ researched a cohort of 58 patients undergoing mpMRI prior to radical prostatectomy. These physicians stated that 'T2 W + DWI + DCE performed significantly better than T2 W + DWI and T2 W alone ($P < 0.001$)'. To put that in the context of this review, mpMRI showed improved ability to diagnose prostate cancer over bpMRI. In 2014, Schimmöller *et al.*³⁷ replicated these findings with their series of 235 consecutive patients undergoing mpMRI-guided biopsies. The AUC for T2-weighted images, DWI, and DCE each alone was 70%, 80%, and 74%, respectively. When combined into the mpMRI, the highest test accuracy was achieved and displayed improved characterization of peripheral over transitional lesions. These researchers warned that when using ≤ 2 MRI imaging modalities, for lack of a better term bpMRI, the test accuracy drops significantly.

Nevertheless, to fully evaluate if bpMRI has comparable accuracy to mpMRI, systematic reviews with comprehensive meta-analyses are needed. Woo *et al.*³⁸ recently undertook this task with their 2018 publication. After a systematic review of the literature, 20 studies assessing the head-to-head comparisons between bpMRI and mpMRI were added to their meta-analysis. Within their analysis, bpMRI yielded a sensitivity of 74% and

specificity of 90% when taking all studies into account. An AUC of 90% was also calculated for bpMRI. mpMRI, on the contrary, displayed an overall sensitivity, specificity, and AUC of 76%, 89%, and 90%, respectively. In their head-to-head comparison, no significant differences in overall sensitivity or specificity were observed. In addition, subgroup analysis was also performed between factors like PI-RADS scoring system, location of ROI within the prostate, MRI coil type, and T system, without identifying differences between mpMRI and bpMRI. Becker *et al.*³⁹ updated this meta-analysis in 2020 with a total of 26 studies comparing mpMRI with bpMRI. This publication is unique as it provides users with real-time interactive graphical figures. The overall sensitivity and specificity of bpMRI was 74% and 90% and mpMRI yielded 76% and 89%. Becker *et al.*'s head-to-head analysis also found no differences between the accuracy of bpMRI and mpMRI. Bass *et al.*²² in 2020 provided physicians with valuable information about clinically significant prostate cancer across the two MRI protocols. With 17 studies included in their bpMRI *versus* mpMRI analysis, comparable rates of clinically significant prostate cancer were identified between the two protocols. In all, several meta-analyses containing a large number of patients have shown bpMRI to be comparable in all terms of overall accuracy, sensitivity, specificity, and utility for the screening and diagnosis of clinically significant prostate cancer. It must be noted that the studies included in these meta-analyses had varying baseline patient characteristics including biopsy-naïve men, active surveillance cohorts, men who received prostatectomy, age, differing NCCN risk categories, and clinical T staging. These varying baseline characteristics make it difficult to empirically compare these data as a single group. However, across differing demographics and cohort types, bpMRI was consistently found to be non-inferior to mpMRI.

Cost advantages and socioeconomic impact

Comparable to mpMRI for the screening and diagnosis of prostate cancer, bpMRI's major advantage is evident in its reduced cost. In a Medicare cohort, Weiner *et al.*⁴⁰ found that an average cost of a prostate biopsy was US\$2020, which was further varied if the patient experienced a complication or not. This cost only increases when the provider includes an mpMRI, which is estimated to cost US\$524 from a 2015

study by Lotan *et al.*⁴¹ However, the average cost of an mpMRI within the United States is highly variable and is dependent on the health care setting and a patient's insurance. bpMRI reduces these costs by omitting the charges associated with contrast agent, additional MRI sequences, and reducing imaging/labor time. Due to these factors, a group out of Korea found that bpMRI cost half as much as an mpMRI employed at their institution. Health care institutions also benefit from the reduced cost of bpMRIs.⁴²

Porter *et al.*⁴³ aimed to compare reimbursement rates of mpMRI to bpMRI and costs associated with labor and direct materials. 2017 reimbursement rates were collected from institutional rates after billing with mpMRI and bpMRI current procedural terminology (CPT) codes 72197 and 72195, respectively. bpMRI had a lower average reimbursement and gross profit of US\$558.61 and US\$510.44, respectively, when compared with mpMRI. However, this reduced profit was also associated with a 59% reduction of direct labor and material costs to the providers. These researchers also highlighted for every 1 mpMRI, an imaging center can undertake 3 bpMRIs. This equates to a projected 138% increase in profit or US\$1531.32 per 45 min of labor when bpMRI is performed and reduced cost incurred by the patient. However, while this publication highlights that omitting a DCE protocol saves 30 min of labor and imaging time, it is the experience of the authors that, at our intuition, a bpMRI only saves on average 3–5 min. Internationally, van der Leest *et al.*⁴⁴ examined the cost and reimbursement of mpMRI *versus* bpMRI across several health care providers in the Netherlands. The costs of an mpMRI and bpMRI were €264.63 and €165.68, respectively. With comparable overall accuracy for PCa, bpMRI offered these clinicians a 37% cost reduction when compared with mpMRI. While within the United States varying costs between providers and intuitions makes it difficult to pinpoint the exact cost advantage of bpMRIs, the Netherlands has a universal health care system.

bpMRI's reduced cost has the unique potential to play a role in combating health care disparities. mpMRI utilization has been shown to vary across socioeconomic classes and races within the United States. Washington *et al.*⁴⁵ reviewed 17 studies with the aim of assessing MRI implementation across socioeconomic lines. Patients with a high socioeconomic class, income greater than

\$69,408, underwent prostate MRI at higher rates with an odds ratio of 1.329 (95% CI, 1.143–1.545) over patients of lower class for the initial diagnosis of prostate cancer.⁴⁶ Fam *et al.*⁴⁷ then analyzed disparities within 9467 men on active surveillance. They further confirmed that patients who lived in areas with a high education level and median household income \geq \$60,001 had a higher likelihood of receiving an mpMRI regardless of clinical presentation of disease. A recent study from Abashidze *et al.*⁴⁸ further elucidated racial disparities among MRI utilization. From 2011 to 2017, MRI has in increasing utilization across all races. Nevertheless, patients from African American and Hispanic heritage were significantly less likely to undergo a prostate MRI when compared with their Caucasian counterparts with similar PSAs. By reducing the cost of prostate MRIs, bpMRI protocol can increase the rates of guideline adherent urologic consultation for these patients experiencing the deterrents of this disparity. This is possible by lowering the socioeconomic barriers to testing through reduced costs; bpMRI has the ability to offer improved care and early cancer detection to all individuals regardless of age, socioeconomic class, or race.

Guidelines regarding bpMRI

There are no current American guidelines regarding the use of bpMRI as opposed to mpMRI. The 'Standard Operating Procedure for Multiparametric Magnetic Resonance Imaging in the Diagnosis, Staging and Management of Prostate Cancer' written by the American Urologic Association (AUA), which is a collaboration between the AUA and the Society of Abdominal Radiology Prostate Disease Focus Panel, states that 'DCE MRI has an important role in PI-RADSv2 for better cancer detection'. They make observations that several European studies have reported non-inferior cancer detection when using bpMRI.⁴⁹ There are several reasons that a clinician may opt to order a bpMRI over a mpMRI, including cost, contrast allergy, or inability to receive contrast due to another medical condition such as end-stage renal disease. These applications could lead to an increased access of MRI in certain patient populations, leading to a decrease in unnecessary biopsies. Internationally bpMRI has had great usage in the European Union. Much of the data regarding sensitive and specificity of bpMRI as compared with mpMRI come from European researchers. One of the landmark publications regarding the

accuracy of bpMRI comes from Denmark concluding that bpMRI has excellent prostate cancer detection rates.²⁷ There are no comprehensive data published about the rates of usage between bpMRI and mpMRI; however, mpMRI is the predominant method of imaging in the current literature.

The future of bpMRI looks promising from both a diagnostic screening tool as well as an economic one. MRI has been evaluated as a viable screening tool for prostate cancer, given the high level of accuracy with both a short total test time and with a lack of intravenous (IV) contrast utilization presents itself as a more exciting option.^{50,51} Furthermore, with the ever-expanding focus on cost-effective medicine, bpMRI can still be employed even in a setting with limited resources given an MRI machine is available. Many studies have evaluated the cost comparisons between bpMRI and mpMRI. mpMRI costs upward of twice as much as a bpMRI due to the additional phases, need for contrast, and overall time required to run a full imaging protocol.⁵² The cost savings benefits of bpMRI are significant as it has comparable rates of prostate cancer detection to mpMRI.

Conclusion

Given the sheer volume of annual prostate cancer diagnoses globally and within the United States, pinpointing the optimal set of diagnostic tools to implement is paramount. As discussed throughout this review, the benefit of using MRI targeted over systemic biopsies is clear. In addition, several researchers have shown that targeted biopsies must be utilized as an adjunct to systemic because alone they do not yield superior or comparable findings.

Nonetheless, the true question is whether bpMRI is a reasonable alternative to mpMRI. bpMRI uses both T2-weighted images with DWI, and mpMRI adds DCE imaging to its protocol. Through single-centered studies and meta-analyse across all identified pertinent published literature, bpMRI is an effective tool for the screening and diagnosis of prostate cancer. When compared with the diagnostic accuracy of mpMRI, bpMRI identifies prostate cancer at comparable rates. From a cost-benefit standpoint, bpMRI has non-inferior detection rates at a lower cost, no contrast needed, shorter exam time, and is not as labor-intensive. These

advantages of bpMRI significantly add value to screening protocols and could increase access to guideline adherent care for patients who are unable to obtain an mpMRI pre-prostate biopsy due to socioeconomic constraints.

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Author contribution(s)

Jacob W. Greenberg: Conceptualization; Data curation; Investigation; Methodology; Software; Visualization; Writing – original draft; Writing – review & editing.

Christopher R. Koller: Investigation; Validation; Writing – original draft.

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References


1. SEER Cancer Stat Facts. *Prostate cancer*. Bethesda, MD: National Cancer Institute, <https://seer.cancer.gov/statfacts/html/prost.html>

2. American Cancer Society. Cancer Statistics Center, <http://cancerstatisticscenter.cancer.org> (accessed 23 December 2021).
3. Carter HB, Albertsen PC, Barry MJ, *et al.* Early detection of prostate cancer: AUA guideline. *J Urol* 2013; 190: 419–426.
4. Albertsen PC. Prostate cancer screening and treatment: where have we come from and where are we going? *BJU Int* 2020; 126: 218–224.
5. Carroll PH and Mohler JL. NCCN guidelines updates: prostate cancer and prostate cancer early detection. *J Natl Compr Canc Netw* 2018; 16: 620–623.
6. Stock C, Hruza M, Cresswell J, *et al.* Transrectal ultrasound-guided biopsy of the prostate: development of the procedure, current clinical practice, and introduction of self-embedding as a new way of processing biopsy cores. *J Endourol* 2008; 22: 1321–1329.
7. Gross MD, Alshak MN, Shoag JE, *et al.* Healthcare costs of post-prostate biopsy sepsis. *Urology* 2019; 133: 11–15.
8. Ristau BT, Allaway M, Cendo D, *et al.* Free-hand transperineal prostate biopsy provides acceptable cancer detection and minimizes risk of infection: evolving experience with a 10-sector template. *Urol Oncol* 2018; 36: 528.e15–528.e20.
9. Eklund M, Jäderling F, Discacciati A, *et al.* MRI-targeted or standard biopsy in prostate cancer screening. *N Engl J Med* 2021; 385: 908–920.
10. Eldred-Evans D, Burak P, Connor MJ, *et al.* Population-based prostate cancer screening with magnetic resonance imaging or ultrasonography: the IP1-PROSTAGRAM Study. *JAMA Oncol* 2021; 7: 395–402.
11. Pereira-Azevedo N, Osório L, Fraga A, *et al.* Rotterdam prostate cancer risk calculator: development and usability testing of the mobile phone app. *JMIR Cancer* 2017; 3: e1.
12. Schroder FH, Hugosson J, Roobol MJ, *et al.* Prostate-cancer mortality at 11 years of follow-up. *N Engl J Med* 2012; 366: 981.
13. Steyn JH and Smith FW. Nuclear magnetic resonance (NMR) imaging of the prostate. *Br J Urol* 1984; 56: 679–681.
14. Berman RM, Brown AM, Chang SD, *et al.* DCE MRI of prostate cancer. *Abdom Radiol (NY)* 2016; 41: 844–853.
15. Bourne R and Panagiotaki E. Limitations and prospects for diffusion-weighted MRI of the prostate. *Diagnostics (Basel)* 2016; 6: 21.
16. Barentsz JO, Richenberg J, Clements R, *et al.* ESUR prostate MR guidelines 2012. *Eur Radiol* 2012; 22: 746–757.
17. Barrett T, Turkbey B and Choyke PL. PI-RADS version 2: what you need to know. *Clin Radiol* 2015; 70: 1165–1176.
18. Purysko AS, Rosenkrantz AB, Turkbey IB, *et al.* Update: PI-RADS version 2.1-a pictorial update. *Radiographics* 2020; 40: E33–E37.
19. Rais-Bahrami S, Siddiqui MM, Vourganti S, *et al.* Diagnostic value of biparametric magnetic resonance imaging (MRI) as an adjunct to prostate-specific antigen (PSA)-based detection of prostate cancer in men without prior biopsies. *BJU Int* 2015; 115: 381–388.
20. Sertkaya Z. Combined biparametric prostate magnetic resonance imaging and prostate-specific antigen in the detection of prostate cancer: a validation study in a biopsy-naive patient population. *Urology* 2016; 95: 223–134.
21. Niu XK, Chen XH, Chen ZF, *et al.* Diagnostic performance of biparametric MRI for detection of prostate cancer: a systematic review and meta-analysis. *AJR Am J Roentgenol* 2018; 211: 369–378.
22. Bass EJ, Pantovic A, Connor M, *et al.* A systematic review and meta-analysis of the diagnostic accuracy of biparametric prostate MRI for prostate cancer in men at risk. *Prostate Cancer Prostatic Dis* 2021; 24: 596–611.
23. Cuocolo R, Verde F, Ponsiglione A, *et al.* Clinically significant prostate cancer detection with biparametric MRI: a systematic review and meta-analysis. *AJR Am J Roentgenol* 2021; 216: 608–621.
24. Kuhl CK, Bruhn R, Krämer N, *et al.* Abbreviated biparametric prostate MR imaging in men with elevated prostate-specific antigen. *Radiology* 2017; 285: 493–505.
25. De Visschere P, Lumen N, Ost P, *et al.* Dynamic contrast-enhanced imaging has limited added value over T2-weighted imaging and diffusion-weighted imaging when using PI-RADSV2 for diagnosis of clinically significant prostate cancer in patients with elevated PSA. *Clin Radiol* 2017; 72: 23–32.
26. Kato D, Ozawa K, Takeuchi S, *et al.* The utility of combined target and systematic prostate biopsies in the diagnosis of clinically significant prostate cancer using Prostate Imaging Reporting and Data System Version 2 based on biparametric magnetic resonance imaging. *Curr Oncol* 2021; 28: 1294–1301.

27. Boesen L, Nørgaard N, Løgager V, *et al.* Assessment of the diagnostic accuracy of biparametric magnetic resonance imaging for prostate cancer in biopsy-naïve men: the biparametric MRI for detection of prostate cancer (BIDOC) Study. *JAMA Netw Open* 2018; 1: e180219.
28. Jambor I, Verho J, Ettala O, *et al.* Validation of IMPROD biparametric MRI in men with clinically suspected prostate cancer: a prospective multi-institutional trial. *PLoS Med* 2019; 16: e1002813.
29. Baur AD, Maxeiner A, Franiel T, *et al.* Evaluation of the Prostate Imaging Reporting and Data System for the detection of prostate cancer by the results of targeted biopsy of the prostate. *Invest Radiol* 2014; 49: 411–420.
30. Rosenkrantz AB, Kim S, Campbell N, *et al.* Transition zone prostate cancer: revisiting the role of multiparametric MRI at 3 T. *AJR Am J Roentgenol* 2015; 204: W266–W272.
31. Radtke JP, Boxler S, Kuru TH, *et al.* Improved detection of anterior fibromuscular stroma and transition zone prostate cancer using biparametric and multiparametric MRI with MRI-targeted biopsy and MRI-US fusion guidance. *Prostate Cancer Prostatic Dis* 2015; 18: 288–296.
32. Sundi D, Kryvenko ON, Carter HB, *et al.* Pathological examination of radical prostatectomy specimens in men with very low risk disease at biopsy reveals distinct zonal distribution of cancer in black American men. *J Urol* 2014; 191: 60–67.
33. Koller CR, Greenberg JW, Shelton TM, *et al.* Prostate cancer lesions by zone and race: does multiparametric MRI demonstrate racial difference in prostate cancer lesions for African American men? *Curr Oncol* 2021; 28: 2308–2316.
34. Patel HD, Doshi CP, Koehne EL, *et al.* African American men have increased risk of prostate cancer detection despite similar rates of anterior prostatic lesions and PI-RADS grade on multiparametric magnetic resonance imaging. *Urology*. Epub ahead of print 21 July 2021. DOI: 10.1016/j.urology.2021.07.005.
35. Sherrer RL, Glaser ZA, Gordetsky JB, *et al.* Comparison of biparametric MRI to full multiparametric MRI for detection of clinically significant prostate cancer. *Prostate Cancer Prostatic Dis* 2019; 22: 331–336.
36. Delongchamps NB, Beuvon F, Eiss D, *et al.* Multiparametric MRI is helpful to predict tumor focality, stage, and size in patients diagnosed with unilateral low-risk prostate cancer. *Prostate Cancer Prostatic Dis* 2011; 14: 232–237.
37. Schimmöller L, Quentin M, Arsov C, *et al.* MR-sequences for prostate cancer diagnostics: validation based on the PI-RADS scoring system and targeted MR-guided in-bore biopsy. *Eur Radiol* 2014; 24: 2582–2589.
38. Woo S, Suh CH, Kim SY, *et al.* Head-to-head comparison between biparametric and multiparametric MRI for the diagnosis of prostate cancer: a systematic review and meta-analysis. *AJR Am J Roentgenol* 2018; 211: W226–W241.
39. Becker AS, Kirchner J, Sartoretti T, *et al.* Interactive, up-to-date meta-analysis of MRI in the management of men with suspected prostate cancer. *J Digit Imaging* 2020; 33: 586–594.
40. Weiner AB, Manjunath A, Kirsh GM, *et al.* The cost of prostate biopsies and their complications: a summary of data on all Medicare fee-for-service patients over 2 years. *J Urol* 2020; 7: 145–151.
41. Lotan Y, Haddad AQ, Costa DN, *et al.* Decision analysis model comparing cost of multiparametric magnetic resonance imaging vs. repeat biopsy for detection of prostate cancer in men with prior negative findings on biopsy. *Urol Oncol* 2015; 33: 266.
42. Lee DH, Nam JK, Lee SS, *et al.* Comparison of multiparametric and biparametric MRI in first round cognitive targeted prostate biopsy in patients with PSA levels under 10 ng/mL. *Yonsei Med J* 2017; 58: 994–999.
43. Porter KK, King A, Galgano SJ, *et al.* Financial implications of biparametric prostate MRI. *Prostate Cancer Prostatic Dis* 2020; 23: 88–93.
44. van der Leest M, Israël B, Cornel EB, *et al.* High diagnostic performance of short magnetic resonance imaging protocols for prostate cancer detection in biopsy-naïve men: the next step in magnetic resonance imaging accessibility. *Eur Urol* 2019; 76: 574–581.
45. Washington C and Deville C Jr. Health disparities and inequities in the utilization of diagnostic imaging for prostate cancer. *Abdom Radiol (NY)* 2020; 45: 4090–4096.
46. Makarov DV, Desai RA, Yu JB, *et al.* The population level prevalence and correlates of appropriate and inappropriate imaging to stage incident prostate cancer in the Medicare population. *J Urol* 2012; 187: 97–102.
47. Fam MM, Yabes JG, Macleod LC, *et al.* Increasing utilization of multiparametric magnetic resonance imaging in prostate cancer active surveillance. *Urology* 2019; 130: 99–105.
48. Abashidze N, Stecher C, Rosenkrantz AB, *et al.* Racial and ethnic disparities in the use of prostate

- magnetic resonance imaging following an elevated prostate-specific antigen test. *JAMA Netw Open* 2021; 4: e2132388.
49. Bjurlin MA, Carroll PR, Eggener S, *et al.* Update of the standard operating procedure on the use of multiparametric magnetic resonance imaging for the diagnosis, staging and management of prostate cancer. *J Urol* 2020; 203: 706–712.
50. Nam RK, Wallis CJ, Stojcic-Bendavid J, *et al.* A pilot study to evaluate the role of magnetic resonance imaging for prostate cancer screening in the general population. *J Urol* 2016; 196: 361–366.
51. Grenabo Bergdahl A, Wilderäng U, Aus G, *et al.* Role of magnetic resonance imaging in prostate cancer screening: a pilot study within the Göteborg randomised screening trial. *Eur Urol* 2017; 71: e81.
52. Hutchinson R and Lotan Y. Cost consideration in utilization of multiparametric magnetic resonance imaging in prostate cancer. *Transl Androl Urol* 2017; 6: 345–354.

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