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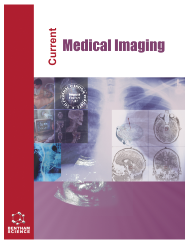


RESEARCH ARTICLE

# Optimizing Prostate Imaging Practices in Saudi Arabian Hospitals: A Comprehensive Analysis of PI-RADS Compliance in Multiparametric MRI

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**Abstract:**

***Background:***

Prostate cancer, a significant contributor to male cancer mortality globally, demands improved diagnostic strategies. In Saudi Arabia, where the incidence is expected to double, this study assessed the compliance of multiparametric MRI (mpMRI) practices with Prostate Imaging-Reporting and Data System version 2 (PI-RADS v2) guidelines across diverse healthcare institutions.

***Methods:***

A survey was distributed to the radiology departments of all tertiary referral hospitals in Saudi Arabia (n=60) to assess their compliance with the technical specifications outlined in PI-RADS v2. Statistical analysis included chi-square, Fisher exact, ANOVA, and Student t-tests to examine the collected data;

***Results:***

The study revealed an overall commendable compliance rate of 95.23%. However, significant variations were observed in technical parameters, particularly between 1.5 Tesla and 3 Tesla scanners and tertiary *versus* non-tertiary hospitals. Notable adherence in certain sequences contrasted with discrepancies in T2-weighted and diffusion-weighted imaging parameters;

***Conclusion:***

These findings underscore the need for nuanced approaches to optimize prostate imaging protocols, considering field strength and institutional differences. The study contributes to the ongoing refinement of standardized mpMRI practices, aiming to enhance diagnostic accuracy and improve clinical outcomes in prostate cancer.

**Keywords:** Multiparametric MRI, PI-RADS, Prostate cancer, Chi-square, ANOVA, Fisher extract.

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|---|---|---|---|

## 1. INTRODUCTION

Prostate cancer (PCa) is the second most common cancer in men, yet it is underdiagnosed in up to 40–60% of patients. This is largely attributed to the limitations of digital rectal exams (DRE) and PSA blood tests, which alone cannot effectively distinguish between benign and clinically significant prostate cancer, leading to potential misdiagnoses and underestimations of the true cancer burden [1]. According to the National Institute for Health and Care Excellence (NICE) guidelines, Multiparametric magnetic resonance imaging (mpMRI) of the prostate should be the initial

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diagnostic test for individuals suspected of having clinically localized PCa [2]. The advancement of mpMRI has significantly enhanced prostate cancer diagnosis by offering more accurate detection and localization of cancerous lesions within the prostate gland [3]. Its use as the primary investigation empowers clinicians to make well-informed decisions regarding biopsy and treatment choices, ultimately leads to better outcomes for patients [4]. Guidelines have emerged to facilitate the seamless integration of prostate mpMR imaging into routine clinical practice. The European Society of Urogenital Radiology (ESUR) introduced the "Prostate Imaging Reporting and Data System" (PI-RADS), using a summary score for lesion assessment through various sequences of mpMRI [5]. This system seeks to establish a global standard for prostate imaging, enhancing cancer detection, localization, characterization, and risk assessment in treatment-naive patients, as well as reducing unnecessary biopsies and treatment for benign and subclinical diseases [6]. Nevertheless, a crucial question arises: to what extent are practitioners adhering to the defined technical parameters detailed in the PI-RADS to achieve optimal image acquisition? This study aims to fill this knowledge gap by investigating the extent of compliance with the minimum acceptable technical parameters for prostate mpMRI as defined by PI-RADS. Our focus extends to tertiary care centers across Saudi Arabia, with the intention of unraveling the current practices and technical standards associated with prostate imaging in the unique healthcare context of the country.

## 2. MATERIALS AND METHODS

The current retrospective study rigorously examined the practices of mpMRI in prostate imaging across Saudi Arabian hospitals. Ethical approval was obtained from the ethics committee (Approval Number: REC-HSD-118-2022), and the study covered a diverse range of hospitals, including tertiary and non-tertiary hospitals.

A survey was initiated in April 2023, involving communication with the radiology departments of 60 hospitals. The study involved 60 institutions and a total of 93 radiologists. The materials used in this study included image sets, DICOM headers, and external reports from these hospitals. The survey aimed to evaluate adherence to the technical specifications outlined in PI-RADS v2. Twenty-one technical standards were identified based on PI-RADS guidelines, extracted from the DICOM headers of an average of three MR images per hospital, and each site's compliance with these standards was assessed. Overall, the study reviewed approximately 180 MR examinations.

A statistical analysis was performed to identify patterns and associations, focusing on the comparison of compliance with mpMRI parameters. Variables such as field strength and institute types were examined to understand factors influencing adherence. The chi-square analysis, along with Fisher exact, ANOVA, and Student's t-tests, was used to assess the association between field strength, institute types, and adherence to specified parameters. Statistical significance was predetermined at a specific alpha level to ensure result reliability.

## 3. RESULTS

### 3.1. Hospital Adherence to PI-RADS Recommendation

A total of 51 hospitals responded to the survey, yielding a response rate of 85%. Among the respondents, 23 clinics (45.1%) utilized a 3 Tesla (T) scanner, while 29 clinics (56.9%) opted for a 1.5 T scanner. Siemens was the choice for 29 clinics, Philips for 8, and General Electric for 14 clinics. The mean pelvic coil channels were 24.54, with a range of 8–64 channels, achieving an overall compliance rate of 85.41%.

High compliance was observed in Coronal T2 (95.83%) and Sagittal T2 (100%). However, adherence to including one sequence covering the aortic bifurcation was noted at 54.16%. The mean T2w Axial Section Thickness was 2.98 mm, demonstrating a compliance rate of 64.58%. Discrepancies were notable in T2w Axial Section Gap (18.75%) and T2w Axial Field Of View (68.75%).

In Diffusion Weighted Imaging (DWI), adherence was strong for the inclusion of DWI sequences (91.66%), but significant variations were observed in DWI parameters, particularly in section gap (32.55%) and field of view (47.72%). Compliance with the recommended B-Value/S/mm$^2$ for both 1.5 T and 3 T scanners was suboptimal. Dynamic Contrast-Enhanced (DCE) sequences demonstrated notable adherence (70.83%) with varying compliance rates in DCE parameters such as section thickness (30.30%) and section gap (20.50%). Temporal resolution (86.25%) and duration (93.33%) exhibited commendable adherence (Table **1**).

**Table 1. Adherence to PI-RADS technical parameters in prostate MRI.**

| Parameter | Compliance (%) |
|---|---|
| Pelvic coil (≥16 channels) | 85.41% |
| Coronal T2 | 95.83% |
| Sagittal T2 | 100% |
| Precontrast axial T1 | 95.83% |
| Postcontrast T1 | 95.83% |
| Aortic bifurcation sequence | 54.16% |
| T2w Axial Section Thickness | 64.58% |
| T2w Axial Section Gap | 18.75% |
| T2w Axial Field Of View | 68.75% |
| DWI Sequence Included | 91.66% |

*(Table 1) contd.....*

| Parameter | Compliance (%) |
|---|---|
| DWI Section Thickness | 90.69% |
| DWI Section Gap | 32.55% |
| DWI Field Of View | 47.72% |
| Highest B-Value (1.5 T) | 25% |
| Highest B-Value (3 T) | 9.52% |
| DCE Sequence Included | 70.83% |
| DCE Section Thickness | 30.30% |
| DCE Section Gap | 20.50% |
| DCE Temporal Resolution | 86.25% |
| DCE Duration | 93.33% |

**Abbreviations:** DWI, Diffusion Weighted Image; DCE, Dynamic contrast enhancement.

**Table 2. Compliance comparison between tertiary and non-tertiary hospitals.**

| Parameter | Tertiary (%) | Non-Tertiary (%) | P value |
|---|---|---|---|
| Pelvic coil (≥16 channels) | 95.23 | 75.59 | <0.001 |
| Coronal T2 | 100 | 91.66 | 0.138 |
| Sagittal T2 | 100 | 100 | >0.999 |
| Precontrast axial T1 | 95.23 | 96.43 | >0.999 |
| Postcontrast T1 | 95.23 | 96.43 | >0.999 |
| Aortic bifurcation sequence | 47.61 | 60.71 | 0.001 |
| T2w Axial Section Thickness | 82.8 | 46.36 | <0.001 |
| T2w Axial Section Gap | 24.1 | 13.40 | 0.011 |
| DCE Sequence Included | 82.8 | 58.86 | <0.001 |

**Table 3. Compliance comparison between 3T and 1.5T MRI systems.**

| Parameter | 3T (%) | 1.5T (%) | P value |
|---|---|---|---|
| Pelvic coil (≥16 channels) | 95.23 | 76.92 | <0.001 |
| Coronal T2 | 95.23 | 96.15 | >0.999 |
| Sagittal T2 | 100 | 100 | >0.999 |
| Precontrast axial T1 | 90.47 | 100 | 0.024 |
| Postcontrast T1 | 90.47 | 100 | 0.024 |
| Aortic bifurcation sequence | 42.85 | 69.23 | <0.001 |
| T2w Axial Section Thickness | 66.66 | 61.53 | 0.833 |
| DWI Section Thickness | 95.23 | 85.71 | 0.024 |
| DWI Section Gap | 38.09 | 28.57 | 0.024 |

### 3.2. Differences in Adherence to PI-RADS Recommendations Between Tertiary and Non-Tertiary Hospitals

Tertiary hospitals had significantly higher compliance rates for several parameters compared to non-tertiary hospitals. For example, the use of a pelvic coil with ≥16 channels (95.23% *vs*. 75.59%, $p < 0.001$) and one sequence covering the aortic bifurcation (47.61% *vs*. 60.71%, $p = 0.001$). Compliance rates were similar between tertiary and non-tertiary hospitals for parameters such as the use of coronal T2 (100% *vs*. 91.66%, $p = 0.138$), sagittal T2 (100% *vs*. 100%, $p > 0.999$), precontract axial T1 (95.23% *vs*. 96.43%, $p > 0.999$), and postcontrast T1 (95.23% *vs*. 96.43%, $p > 0.999$). Tertiary hospitals also demonstrated better adherence to DCE parameters, including DCE sequence inclusion (82.8% *vs*. 58.86%, $p < 0.001$) (Table **2**).

### 3.3. Differences in Adherence to PI-RADS Recommendations between Hospitals with 3 Tesla and 1.5 Tesla MRI Machines

Hospitals with 3 T MRI machines demonstrated higher compliance rates for the use of a pelvic coil with ≥16 channels (95.23% *vs*. 76.92%, $p < 0.001$), precontrast axial T1 (90.47% *vs*. 100%, $p = 0.024$), postcontrast T1 (90.47% *vs*. 100%, $p = 0.024$), one sequence covering the aortic bifurcation (42.85% *vs*. 69.23%, $p < 0.001$), and T2-weighted axial field of view of 120-200 (76.19% *vs*. 57.69%, $p < 0.001$). However, hospitals with 1.5 T MRI machines showed higher compliance rates for parameters such as T2-weighted axial section thickness of 3 mm (66.66% *vs*. 61.53%, $p = 0.833$), DWI section thickness of ≤4 mm (95.23% *vs*. 85.71%, $p = 0.024$), and DWI section gap of 0 (38.09% *vs*. 28.57%, $p = 0.024$) (Table **3**).

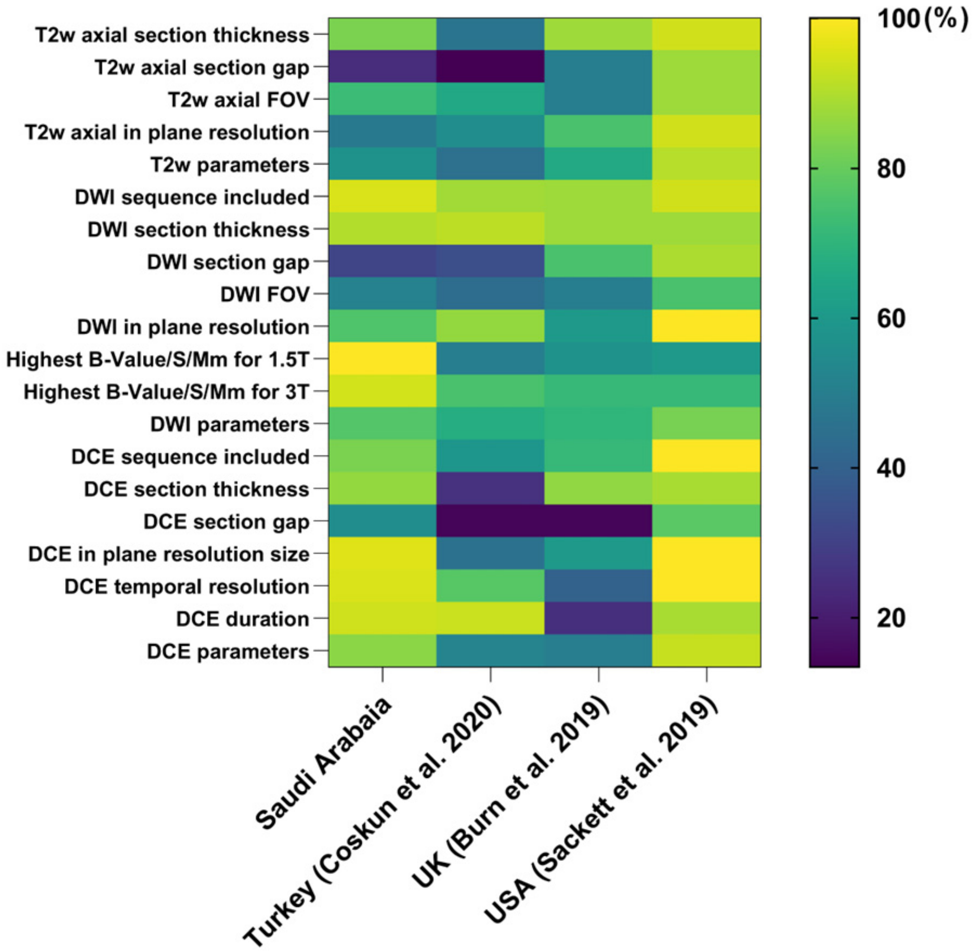


**Fig. (1).** Comparison of Adherence to PI-RADS Technical Parameters in Prostate MRI Across Different Countries. Heatmap matrix compares the adherence to PI-RADS technical parameters in prostate MRI across Saudi Arabia (2024), Turkey (2020), the United Kingdom (2019), and the United States (2019). The values represent the compliance percentages for each parameter in the respective countries.

## 4. DISCUSSION

The study's findings on the adherence of Saudi Arabian hospitals to PI-RADS guidelines offer valuable insights into regional practices and underscore the need for standardization and consistency in technical parameters. The analysis revealed varying levels of compliance across different parameters, indicating areas of strength and areas that require improvement.

The lowest compliance rate was observed for the maximum b-value for DWI at 3T MRI, suggesting a potential gap in the implementation of advanced imaging techniques. On the other hand, the highest adherence was found for the T2-weighted image sagittal plane, indicating a strong adherence to basic imaging protocols. The comparison between tertiary and non-tertiary hospitals revealed significant differences in compliance rates, highlighting the added value for ongoing education, quality assurance, and feedback [7, 8]. When comparing adherence between tertiary and non-tertiary hospitals, significant differences were noted, with tertiary hospitals demonstrating higher compliance rates for several parameters. This suggests that tertiary hospitals may have more resources or expertise dedicated to prostate imaging, allowing them to adhere more closely to established guidelines. These findings underscore the importance of ongoing education and training for radiologists and technologists in non-tertiary hospitals to improve adherence to PI-RADS guidelines and enhance the quality of prostate imaging across all healthcare settings [8].

Comparison with previous studies in Turkey [9 - 11], the United Kingdom [12], and the United States [13] revealed varying levels of adherence to PI-RADS guidelines, with Saudi Arabian hospitals generally demonstrating higher adherence to certain parameters, such as T2-weighted axial section thickness (Fig. **1**). However, adherence to other parameters, such as T2-weighted axial section gap and in-plane resolution, was lower in Saudi Arabia compared to the United Kingdom and the United States. Regarding DWI parameters, Saudi Arabian hospitals showed higher adherence compared to Turkey, the United Kingdom, and the United States. However, adherence to DWI section thickness and gap was lower in Saudi Arabia compared to all other countries. Regarding DWI parameters, Saudi Arabian hospitals showed higher adherence compared to Turkey, the United Kingdom, and the United States. However, adherence to DWI section thickness and gap was lower in

Saudi Arabia compared to all other countries. This discrepancy highlights the need for focused efforts to improve adherence to specific DWI parameters, which are crucial for accurate assessment of prostate lesions. There are as yet no standardized DW-MRI techniques, and a large variety of imaging parameters exist for DWI in terms of the number and size of b values. Performing DWI requires at least two b factors, which allows for the calculation of the ADC [14]. A high b value permits high diffusion weighting, and tumor tissue often has higher signal intensity or lower ADC values on ADC maps compared with native tissue. The typical b value for prostate imaging varies in the range of 0–1,500 s/mm2. Some studies [15, 16] have suggested that the use of a b value of 2,000 s/mm2 is diagnostically superior to that of 1,000 s/mm2.

DCE is included in the PI-RADS v2 and v2.1 guidelines; however, the role of DCE sequences in the diagnosis and staging of prostate cancer remains controversial, as studies without DCE, such as biparametric MRI (bpMRI), have shown comparable accuracy [17]. In the current study, Saudi Arabian hospitals demonstrated higher adherence to including DCE sequences and achieving DCE temporal resolution compared to Turkey and the United Kingdom, but lower adherence compared to the United States. This suggests that while Saudi Arabian hospitals are generally following guidelines for DCE imaging, there is still room for improvement to align more closely with international standards. Despite PI-RADS guidelines recommending the use of 3T MRI systems, approximately 36% of hospitals in Saudi Arabia used 3T systems, with the rest utilizing 1.5T systems. A comparison between 1.5T and 3T MRI systems by Ullrich *et al*. [16] showed that the signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) for T2-weighted images are comparable for both field strengths. However, for DWI, the SNR and CNR are significantly lower at 1.5T. DWI is particularly important for recognizing clinically significant PCa in the peripheral zone (PZ), making 3T scanning preferable [17]. Further investigations are necessary to determine whether 1.5T MRI has the same diagnostic value as 3T MRI on modern MRI systems for clinical decision-making, such as the need for biopsy and biopsy yields.

In the current study, hospitals with 3T MRI machines showed higher compliance in parameters like pelvic coil channels, T1 and T2 sequences, aortic bifurcation coverage, and DWI sequence inclusion. Conversely, hospitals with 1.5T MRI machines had higher adherence in parameters such as T2-weighted axial section thickness and DWI section thickness. Notably, studies in Turkey [9] and the United States [12] reported higher adherence to some PI-RADS v.2 guidelines at 3T for T2-weighted and DWI parameters, similar to our findings.

The use of an endorectal coil in prostate MRI is another area of contention. While endorectal coils can improve SNR and spatial resolution, leading to more detailed images, their use can be uncomfortable for patients and may increase examination time and cost. Recent advances in MRI technology, such as the development of multi-channel phased-array coils, have reduced the necessity of endorectal coils by providing high-quality images without the associated discomfort [18, 19]. In the current study, almost all the hospitals surveyed did not employ endorectal coils.

The study has several limitations that should be considered when interpreting the results. The sample size might have been limited, affecting the representativeness of the results. Additionally, reliance on self-reported data or medical record reviews could introduce bias or inaccuracies. The cross-sectional design of the study limits its ability to establish causality or assess changes in adherence over time.

Despite these limitations, the study's findings provide valuable insights into the current state of adherence to PI-RADS guidelines in Saudi Arabian hospitals and highlight areas for improvement. Moving forward, efforts should be made to increase awareness and adherence to PI-RADS guidelines in Saudi Arabian hospitals. This could involve targeted educational programs, quality assurance initiatives, and regular audits to ensure compliance. Collaboration with international partners could also provide valuable insights and benchmarking opportunities to improve adherence to best practices in prostate imaging.

## CONCLUSION

Overall, the study provides valuable insights into the current state of adherence to PI-RADS guidelines in Saudi Arabian hospitals. Furthermore, efforts should be made to increase awareness and adherence to PI-RADS guidelines through targeted educational programs, quality assurance initiatives, and collaboration with international partners. These initiatives will contribute to improving the quality and accuracy of prostate imaging, ultimately leading to better clinical outcomes for patients.

## AUTHORS' CONTRIBUTION

It is hereby acknowledged that all authors have accepted responsibility for the manuscript's content and consented to its submission. They have meticulously reviewed all results and unanimously approved the final version of the manuscript.

## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| **PCa** | = | Prostate cancer |
| **CNR** | = | Contrast-to-noise ratio |
| **PZ** | = | Peripheral zone |

## ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the ethics committee (Approval Number: REC-HSD-118-2022), covering a diverse range of hospitals, including tertiary and non-tertiary hospitals.

## HUMAN AND ANIMAL RIGHTS

All procedures performed in studies involving human participants were in accordance with the ethical standards of institutional and/or research committee and with the 1975 Declaration of Helsinki, as revised in 2013.

## CONSENT FOR PUBLICATION

Informed consent was obtained from all subjects involved in the study.

## STANDARDS OF REPORTING

STROBE guidelines were followed.

## AVAILABILITY OF DATA AND MATERIAL

All data generated or analysed during this study are included in this article.

## FUNDING

None.

## CONFLICT OF INTEREST

The authors declared no conflict of interest, financial or otherwise.

## ACKNOWLEDGEMENTS

Declared none.

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