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Prostate MRI and image quality: The radiologist's perspective

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ABSTRACT

Multiparametric MRI (mpMRI) of the prostate plays an important role in the healthcare pathway of prostate cancer. The implementation of the guidelines resulted in an almost vertical increase in the number of prostate MRI examinations. High image quality is important in the diagnostic pathway of prostate cancer. Standardization of prostate MRI quality using objective and pre-defined criteria is of utmost importance.

1. Introduction

While prostate magnetic resonance imaging (MRI) was first introduced in the 1980's it was not performed widely and remained for many years a staging examination in men with known prostate cancer and performed in large academic centers with clinical research interests. At present, multiparametric MRI (mpMRI) of the prostate plays an important role in the healthcare pathway of prostate cancer. Advances in MRI technology, including coil technology, higher field strengths, and sequence development (i.e. diffusion-weighted imaging), resulted in a major improvement in image quality. In the past decade, there has been a major shift and change in the role of mpMRI [1]. In 2018, three level I evidence papers have led to the implementation of multiparametric MRI in international guidelines [2–4]. The implementation of the guidelines resulted in an almost vertical increase in the number of prostate MRI examinations. As a result, the feasibility of performing a large volume of prostate MRIs is challenging. Although almost all academic centers perform prostate MRIs, only 30% of community hospitals do so.

2. Prostate cancer background and role of MRI

There are 2 distinct types of prostate cancer based on histopathological analysis using the Gleason grading system. The indolent clinically insignificant – grade group 1 and all others -Grade groups 2 and higher. The major feature is the Gleason pattern 4 – which is never present in Grade group 1. Thus, Grade group 1 diagnosis relegates men to the indolent group- often requiring no treatment and at best active surveillance. These cancers may progress and thus surveillance is preferred. The major impact of MRI is in the detection and diagnosis of clinically significant disease. The latter is defined as prostate cancer with a pathological Gleason grade 4 pattern. Coincident with this clinical need was the research into the role of DWI. It is now well established that DWI can detect Gleason pattern 4 disease, apparent as focal areas of highly restricted Diffusion. There have been many publications supporting the role of pre-biopsy MRI to identify men with suspicious lesions requiring biopsy. The data culminated in the 2018 NEJM paper reporting a multi-center randomized controlled trial of men undergoing a pre- biopsy MRI compared to men with no pre-biopsy MRI [5]. This study showed that in biopsy naïve men MRI and a risk assessment analysis was superior to the then conventional standard transrectal ultrasound-guided biopsy. A pre-biopsy prostate MR exam is now widely accepted as routine clinical care Thus MR exams can allow for the separation of men into Grade group 1 and grade group 2 or higher. High prostate MRI quality is required for precise biopsy targeting as well as to rule out significant prostate cancer. Poor image quality is associated with increased uncertainty and reduced biopsy yield [6,7]. The image quality may also be hampered by rectal spams, hip implants, susceptibility artifacts (rectal gas), or patient movement. Several studies have shown that MRI quality varies substantially between centers and scanners as well as variation in compliance with recognized Prostate Imaging Reporting and Data System (PI-RADS) v2 standards [8–10].

As a result of the large body of data -much of it level-1 evidence, much work has gone into developing standard technical approaches and interpretation methods. A group of international experts have developed and continue to refine the PI-RADS. The PI-RADS guideline resulted from a successful collaboration between members of the American College of Radiology (ACR), the international working group for prostate mpMRI convened by the AdMeTech foundation, and the European

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Society of Urogenital Radiology (ESUR). The ACR PI-RADS committee formed from the latter 3 groups was then established in 2012 [11].

Magnet field strengths and homogeneity have increased, with many exams now performed routinely at 3 T, leading to major improvements in signal-to-noise and overall exam quality. PI-RADS outlines guidance on minimal technical standards [8–10]. There are 3 pulse sequences that make up the typical prostate MRI exam namely anatomical T2-weighted imaging (T2W), DWI and dynamic intravenous Gadolinium contrast-enhanced (DCE) MRI. Multi-planar T2W acquisitions are advised and ideally, all 3 planes should be acquired. DCE acquisitions are also important and the early arterial phase being the most valuable component. As with so many other abdominopelvic MR exams, these are now routine and generally of average to good quality. All of these have been very helpful in achieving excellent prostate MRI exams. A major area of concern remains the DWI acquisition. The PI-RADS standard recommends a low and high b-value acquisition- with a high b-value of 1400 or greater. This specific sequence is without doubt essential and the most valuable in all prostate MR exams. This sequence provides unique, highly accurate data for the identification of focal clinically significant prostate cancer within the gland. The presence of a focal lesion of highly restricted diffusion is very well correlated with focal Gleason pattern 4 prostate cancer.

So, now that many institutions/imaging facilities are performing mpMRI examinations, expectations and standards for image quality are of preeminent importance. A high-quality prostate MRI is a challenging exam to perform requiring technologist and radiologist education, training, experience, and expertise. Resources to support exam quality needs are in short supply.

To achieve diagnostic excellence, we must address the current deficits in the imaging pathway to ensure a consistent high-quality mpMRI exam: starting with the MRI technical acquisition, educating and training technologists and radiologists, and reducing interpretation errors and inter-reader variability [12]. While PI-RADS has established minimal requirements for acquisition parameters for the exam, it is unclear how well these are understood or adopted. In fact, even when they are it appears this does not always result in a high-quality exam [13]. There is major pressure in all MR facilities to reduce the exam time, to increase efficiency and productivity. This often comes with a cost on the quality because faster exams can lead to lower quality.

There are many amenable steps on the path to diagnostic excellence-some of the ways prostate MR can be improved starting with the MR device vendors (such as magnet performance/product sequences, the artificial intelligence behind exam performance and denoising techniques), improved MR pulse sequences (reliable and robust acquisitions), and technical know-how at every MR facility. Essentially there are 3 major sets of factors that contribute to overall quality - these are technical, radiology team factors, and patient-related factors. When reviewing the literature and attempting to assess quality and adherence to guidelines all three areas should be addressed. There are currently no specific training requirements for exam performance, limited phantoms for testing magnet capabilities, and no rigorous QA programs for magnets, images, or interpretation skills. There are no mandatory or even voluntary requirements for tumor boards, case follow-up, or regular testing of the team members at each site. There are now multiple groups of stakeholders assisting in Quality Improvement efforts- namely the ACR, ISMRM, and ESUR.

3. Guidelines

There is no one global guideline for patient selection, risk prediction, and prostate cancer workflows, as each country, professional society, and healthcare systems may have its own set of guidelines based upon loco-regional clinical practice. These are critical when defining the success of any one component of the pathway. There are many suggested guidelines for the integration and adoption of prostate MRI in the clinical care pathway of men suspected of having prostate cancer [14].

For example, the ACR-RADS. There is a large collection of reporting and data standards particularly focused on cancer imaging. These have been established assembled and managed under the auspices of the ACR. These so-called RADS include PI-RADS, BI-RADS, LI-RADSs, and many others. All of these RADS are considered living documents that is they are constantly being updated and new versions are released on a regular basis [15].

The leading set of guidelines for prostate cancer exams comes from the PI-RADS committee. This guideline is specifically designed to improve detection, localization, characterization, and risk stratification in patients with suspected cancer in treatment naïve prostate glands. This comprises a set of minimal technical standards for exam acquisition, a lexicon of word descriptors for exam findings and the radiologist's assessment scores with definitions and examples. The most recent version is 2.1 which provide the following [16]:

1. An outline of a minimal set of technical standards for the prostate MR exam acquisition and general statements regarding field strength: either 1.5 T or 3.0 T is advised. The endorectal coil is not mandated and only suggested when using 1.5 T. These include the minimum technical standards for prostate MRI exam acquisition.
2. A set of assessment scores for rating individual suspicious lesions, with illustrations and the current version 2.1 [16]. These scores 1 to 5 are defined, using a pre-selected lexicon of approved descriptive terms to express MR image finding. The PI-RADS system categorizes prostate lesions based on the likelihood of cancer according to a five-point scale, defined as the following:

   PI-RADS 1 – Clinically significant cancer is highly unlikely to be present.
   PI-RADS 2 – Clinically significant cancer is unlikely to be present.
   PI-RADS 3 – The presence of clinically significant cancer is equivocal.
   PI-RADS 4 – Clinically significant cancer is likely to be present.
   PI-RADS 5 – Clinically significant cancer is highly likely to be present.

In the US, we have recognized that prostate MR image quality is inconsistent, possibly leading to missed diagnoses and the inability to use the images in subsequent procedures, adversely impacting patient care. Thus, a recent initiative has been undertaken by the ACR learning network. This collaborative initiative is a unique and novel approach performed by teams of sites who all meet and develop measures to support quality improvement metrics developed together [17]. The teams from each site involve individuals involved in all steps from scheduling the exam, to technologists, MR managers, radiologists, referring physician representatives and individuals with previous experience with quality improvement.

In the UK there is a set of guidelines provided by the United Kingdom National Institute for Health and Care Excellence (NICE). These cover prostate cancer diagnosis and management, advising the use of multiparametric MRI as the first-line investigation for all people with suspected clinically localized prostate cancer. These are closely adhered to the UK's national health system (NHS). A summary of these is provided in this paper and more detailed information can be found at NICE web. A prostate MR is not offered to men with prostate cancer who are unlikely to go on to radical treatment. It is recommended for men suspected of having localized clinically significant prostate cancer and an MR informed prostate biopsy is advised for men with a Likert score 3 or higher finding on MRI. One area of significant agreement has been the "biopsy avoidance" approach, as NICE advises against biopsy in men with Likert scores less than 3. This has not been followed outside the UK, yet.

In the US it is still common to go straight to biopsy without MRI and even when MR is negative many men will still have a systematic, non-targeted biopsy performed. The rationale for this is that MR does have a false negative rate. While this is true, it is generally low. However, we

must work to reduce this false negative rate. One of the major contributors has been poor image quality.

There is also a set of guidelines from the European Association of Urology (EAU)-European Association of Nuclear Medicine (EANM)-European Society for Radiotherapy and Oncology (ESTRO)-European Society of Urogenital Radiology (ESUR)-International Society of Geriatric Oncology (SIOG) [18] which include MRI for screening, diagnosis and local treatment of clinically localized prostate cancer. A joint panel of representatives from these groups reviewed the literature and conclusions were published. One relevant recommendation, given a strong rating, is for screening and individual early detection- -in asymptomatic men with PSA level 3–10 ng/mL and a normal digital rectal exam (DRE) use one of the following tools for biopsy indication: a risk calculator or mpMRI. These tools are of course very different. There are multiple risk calculators which vary in value with population prevalence and provide no biopsy guidance. The mpMRI results do also vary with population prevalence but do provide unique spatial localization of targets – thus informing the biopsy procedure. Thus, in reality, the mpMRI is being used more than a risk calculator, as it can be objective.

Many of the guidelines and recommendations are in active use today in clinical practice. Adherence is difficult to assess but many are being evaluated and refined as time and experience expands. the next sections will address the early standardization of quality evaluations which are much needed. Work continues and as previously outlined by a set of ACR stakeholders much remains to be done [19].

3.1. PI-QUAl

The PRECISION trial has led to the prostate imaging quality (PI-QUAL) system [5]. The PI-QUAL is a scoring system specifically designed to evaluate the technical quality of prostate MRI [20]. The quality is evaluated against a set of objective criteria (defined by PI-RADS guidelines) as well as subjective criteria. The PI-QUAL uses a Likert scale from 1 to 5, where 1–2 means that the sequences are below the minimum standard of diagnostic quality, 3 means that the scan is of sufficient diagnostic quality, and 4–5 means that the sequences are of adequate diagnostic quality. As a result, PI-QUAL cannot be applied for biparametric MRI.

The purpose of PI-QUAL is to provide a standardized and objective assessment of the imaging quality, which can help radiologists and clinicians interpret the results accurately. The PI-QUAL reproducibility has been reported from moderate to good interreader agreement [21–23]. Lower PI-QUAL scores and poorer image quality is associated with increased uncertainty in the decision-making and clinical outcomes of repeat imaging and biopsy of low-to-intermediate risk cases [21]. Furthermore, the highest variability in the quality of mpMRI was seen in the DCE sequences, followed by DWI and T2W imaging. In a review of studies published within the past 5 years in which prostate MRI quality was reported, a poor inter-reader agreement was observed when institution-specific criteria were used, with DWI being the diagnostic sequence with the highest variability [24]. The new version of the PI-QUAL scoring system should include elements of lesion detection, anatomical features, bi-parametric MRI as well as quantitative measures. Furthermore, validation and outcome date are required for further implementation. Ultimately, artificial intelligence could help us to implement the PI-QUAL scoring without user interaction and even further to integrate this directly within the sequence.

4. Conclusion

Multiparametric prostate MRI is incorporated in clinical guidelines resulting in high clinical demand from referring physicians. High image quality is important in the diagnostic pathway of prostate cancer. Standardization of prostate MRI quality using objective and pre-defined criteria is of utmost importance. The first steps have been taken but they need to undergo refinements before global clinical adaptation will take place.

CRediT authorship contribution statement

Jurgen J. Fütterer: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Clare Tempany:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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