



Effect of a dedicated PI-QUAL curriculum on the assessment of prostate MRI quality

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ABSTRACT

Purpose: The Prostate Imaging Quality (PI-QUAL) score is a metric to evaluate the diagnostic quality of multiparametric magnetic resonance imaging (MRI) of the prostate. This study evaluated the impact of a prostate MRI quality training lecture on the participant's ability to assess prostate MRI image quality.

Methods: Eighteen in-training-radiologists of varying experience in reviewing diagnostic prostate MRI assessed the image quality of ten examinations. Then, they attended a dedicated lecture on MRI quality assessment using the PI-QUAL score. After the lecture, the same participants evaluated the image quality of a new set of ten scans applying the PI-QUAL score. Results were assessed using receiver operating characteristic (ROC) analysis. The reference standard was the PI-QUAL score assessed by a fellowship trained abdominal radiologist with experience in reading prostate MRI.

Results: There was a significant improvement in the average area under the curve (AUC) for assessment of prostate MRI image quality from baseline (0.82; [0.576 – 0.888]) to post teaching (1.0; [0.954–1]), with an improvement of 0.18 ($p < 0.03$). When ROC curves were computed for different cohorts stratified based on year of training, difference ranged from 0.48 for second year residents to 0.32 for fourth year residents ($p < 0.001$ – 0.01). For abdominal imaging fellows, the pre-teaching AUC was 0.9 [0.557–1] and post teaching AUC was 1 [0.957–1], a difference of 0.1 ($p = 0.20$).

Conclusions: A dedicated lecture on PI-QUAL improved the ability of radiologists-in-training to assess prostate MRI image quality, with variable impact depending on year of training.

1. Introduction:

Prostate cancer (PCa) is the one of the most frequently diagnosed cancer in men worldwide [1]. Multiparametric magnetic resonance imaging (MRI) of the prostate has become a crucial test for the detection of clinically significant PCa and monitoring its progression [2–4]. Over the years, there has been increased utilization of MRI for both diagnostic and management of PCa [2–4] - high quality images are essential for the diagnosis of clinically significant PCa [2]. Inadequate image acquisition has been associated with decreased accuracy, increased uncertainty, and increased biopsy procedures with relatively lower cancer yield [2,4–9]. Various factors can degrade image quality such as patient movements, rectal spasms, metal implants, and air near the rectum [5,6]. The Prostate Imaging-Reporting and Data System (PI-RADS) version 2.1 provides minimum quality standards for performing MRI of the prostate [10], and

there has recently been an increased emphasis on quality standards. The PRECISION trial recently demonstrated that MRI-targeted biopsies outperformed standard transrectal ultrasound-guided biopsies for detection of PCa [11–13], the results of which are dependent on the quality of the MRI.

To address the increasing importance of MRI quality, Giganti et al. introduced the Prostate Imaging Quality (PI-QUAL) score as a standardized system which assesses the quality of key sequences in prostate MRI [14]. Adequacy of each of the dominant sequences i.e., T2-weighted images, diffusion-weighted images (DWI), and dynamic contrast enhanced (DCE) images was scored by utilizing objective quality criteria set by PI-RADS v2.0 guidelines as well as additional subjective image quality parameters, with each of these scores contributing to the final PI-QUAL score. The PI-QUAL score is based on a Likert scale from 1 to 5. A PI-QUAL score of 1 or 2 indicates that the MRI scan is inadequate in

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diagnostic quality to include or exclude significant lesions. A PI-QUAL score of 3 indicates that the MRI images are of sufficient diagnostic quality to rule in lesions, however lesions cannot be ruled out. A PI-QUAL score of 4 or 5 indicates a high-quality MRI scan and all clinically significant lesions can be ruled in and ruled out. The PI-QUAL scoring system has demonstrated moderate to strong inter-reader agreement between experienced radiologists [15–17].

In a consensus statement, experts from the European Society of Urogenital Radiology (ESUR) and European Association of Urology - Section of Urologic Imaging (ESUI) not only recommended checking and reporting prostate MRI image quality [18], but also recommended radiologists participate in dedicated courses, supervised education, and regular performance assessments [18]. A pilot study demonstrated that a dedicated teaching course and workshop for PI-QUAL may be effective for both radiologists and non-radiologists [15]. However, the participants were a diverse group of radiologists, urologists, computer scientists, and physicists with a wide range of prostate MRI experience. Evaluating the utilization of the PI-QUAL system in a larger group of radiologists stratified by experience levels may be helpful in illuminating the strengths and weaknesses of PI-QUAL and assess for areas of improvement in future iterations. In this study, we investigated the effectiveness of an educational intervention for radiologists-in-training in evaluation of prostate MRI quality.

2. Materials and methods

2.1. Setting and participants

This study was approved by the XXXX Institutional Review Board. In-training radiologists were invited from the department of Diagnostic Radiology at XXXX to participate. The prerequisite for participation was an understanding of different MRI sequences, general knowledge of prostate MRI anatomy, previous exposure to prostate MRI, and no prior knowledge of the PI-QUAL scoring system.

2.2. Clinical cohort and reference standard

A total of twenty prostate MRIs were selected from twenty different patients between September 2022 and November 2022. To represent a realistic sample of prostate MRIs for PI-QUAL application, these imaging studies were chosen at random without specific exclusion criteria. The studies were separated into two folders in our picture archiving and communication system (PACS). Ten randomly selected studies were assigned to a pre-intervention folder and other ten studies were assigned to a post-intervention folder. Participants were provided instructions regarding access to these folders.

The principal investigator (X1.X1.) is a fellowship trained abdominal radiologist experienced radiologist in genitourinary imaging and prostate MRI (>3 years of experience in prostate MRI, reporting > 500 scans per year). Evaluations by the principal investigator was used as the reference standard for assessment of participants' performances before and after the educational intervention.

2.3. Mri

MRI examinations were performed on three types of 3 Tesla MRI scanners: Magnetom Vida (Siemens Healthineers, Erlangen, Germany.), Magnetom Skyra (Siemens Healthineers, Erlangen, Germany), and one Magnetom Trio (Siemens Healthineers, Erlangen, Germany). A body phased-array coil was utilized with both small field-of-view and large field-of-view sequences. All MRI studies included T2-weighted sequences obtained in axial, coronal, and sagittal planes, axial diffusion-weighted imaging with highest b-value of 1400 s/mm², and a dynamic contrast-enhanced sequence utilizing Gadobenate Dimeglumine (MultiHance) (Bracco S.p.A., Milan, Italy) (Supplemental Table 1).

2.4. Educational intervention

In the two weeks prior to a dedicated PI-QUAL lecture, participants were asked to independently complete a scoring sheet for each of the ten patients in the pre-intervention folder in our PACS (Fig. 1). The scoring sheet included evaluation of the adequacy of the T2-weighted, diffusion-weighted, and dynamic contrast-enhanced sequences. Participants were also asked whether they felt confident in diagnosing or excluding PCa and if they would have repeated the scan due to inadequate image quality. Scoring sheets were returned prior to the lecture. The pre-intervention assessments were stratified into two categories: adequate and inadequate. If a participant marked that they felt confident in diagnosing or excluding PCa due to image quality, then the assessment was classified as "adequate".

After the lecture, participants were asked to independently evaluate the image quality of studies from ten new patients in the post-intervention folder on our PACS. Participants utilized the PI-QUAL scoring sheet for each study (Fig. 2). The scoring sheets were returned for data aggregation. Image quality was stratified into two categories: adequate and inadequate. Adequate scores included PI-QUAL 4 and PI-QUAL 5. Inadequate scores included PI-QUAL 1, PI-QUAL 2, and PI-QUAL 3.

2.5. Lecture framework

The lecture was titled "Prostate MRI quality and the PI-QUAL score", was held remotely by one of the developers of PI-QUAL (Francesco Giganti, MD PhD - Division of Surgery & Interventional Science, University College London, London, UK; Department of Radiology, University College London Hospitals NHS Foundation Trust, London, UK), via a video-meeting platform and was recorded for participants who were unable to attend at the time. The lecture lasted for approximately one hour with a brief questions and answers session at the end. The lecture was divided into three sections:

Section 1 consisted of an introduction to prostate MRI including its history, increasing importance in diagnostic and treatment pathways, and increasing importance of prostate MRI quality assessment. **Section 2** consisted of an overview of the PI-QUAL score and a detailed breakdown of the PI-QUAL scoring sheet. This included explanations of the technical parameters and visual assessments as noted on the scoring sheet with examples given throughout the presentation. The anatomy of the prostate gland was reviewed. **Section 3** consisted of application of the PI-QUAL score. Three cases were systematically analyzed and actively discussed. Final statements were made regarding the impact the PI-QUAL system has had so far and future directions.

2.6. Statistical analysis

The primary outcome was to determine the change in the average area under the curve (AUC) for detection of adequate and inadequate image quality before and after the educational intervention.

The pre-intervention scoring sheet was utilized to stratify participant results into baseline adequate and inadequate image quality categories. The post-intervention PI-QUAL scoring sheet was utilized to stratify participant results into post-intervention adequate and inadequate image quality categories. Adequate image quality corresponded to PI-QUAL 4–5 and inadequate image quality corresponded to PI-QUAL 1–3.

Receiver operating characteristic (ROC) curves were based on generalized linear mixed models with random effects on readers and cases, generalizing the Obuchowski-Rockette method described by Liu et al. [19,20]. For each ROC curve and AUC value, 95% confidence intervals were computed utilizing conditional bootstrap resampling (B = 10,000 samples).

The p values were computed by normal approximation and considered significant when $p < 0.05$. All statistical analyses were performed in R v. 4.2.2 (R Foundation for Statistical Computing).



Name:

Please state your department and level of training:

Experience in prostate MRI (in months/years):

Number of prostate MRI scans reported yearly (if applicable):

Quality Assessment - Assess the image quality for each sequence. Circle, highlight, or underline whether the sequence is adequate or inadequate. State a reason for your evaluation.

Scan number:

T2-weighted imaging (T2-WI)

Adequate or Inadequate

Reason:

Diffusion-weighted imaging (DWI)

Adequate or Inadequate

Reason:

Dynamic contrast enhanced (DCE)

Adequate or Inadequate

Reason:

Would you be confident in diagnosing or excluding prostate cancer based on these images?

Yes No

Would you repeat the scan?

Yes No

Fig. 1. Scoring sheet for pre-teaching scans.

3. Results

A total of eighteen participants completed this study. Participants included five residents in their second year of radiology residency (R2), four residents in their third year of radiology residency (R3), five residents in their fourth year of radiology residency (R4), and four abdominal imaging fellows (F).

3.1. PI-QUAL score

In the pre-intervention images, the reference standards were reported as follows: 2/10 (20%) scans were scored PI-QUAL 2, 3/10 (30%) scans were scored PI-QUAL 3, 5/10 (50%) scans were scored PI-QUAL 4. In the post-intervention images, the reference standards were reported as follows: 1/10 (10%) scans were scored PI-QUAL 2, 6/10 (60%) scans were scored PI-QUAL 3, 3/10 (30%) scans were scored PI-QUAL 4 (Fig. 3).

3.2. Accuracy in assessing image quality

There was a significant improvement in the average AUC for assessment of adequate and inadequate prostate MRI image quality from baseline (0.82; [0.576 – 0.888]) to post teaching (1.0; [0.954–1]), an improvement of 0.18 ($p = 0.03$) (Fig. 4A).

ROC curves and corresponding AUC were also calculated for different cohorts stratified based on year of training (Fig. 4B–4E). For R2 residents, the pre-teaching AUC was 0.5 [0.424–0.813] and post teaching AUC was 0.98 [0.672–1], a difference of 0.48 ($p < 0.001$). For R3 residents, the pre-teaching AUC was 0.6 [0.397–0.844] and post teaching AUC was 1 [0.725–1], a difference of 0.40 ($p = 0.002$). For R4 residents, the pre-teaching AUC was 0.68 [0.423–0.923] and post teaching AUC was 1 [0.838–1], a difference of 0.32 ($p = 0.01$). For abdominal imaging fellows, the pre-teaching AUC was 0.9 [0.557–1] and post teaching AUC was 1 [0.957–1], a difference of 0.1 ($p = 0.20$).

Scan & site number:



Prostate Imaging QUALity control (PI-QUAL) scoring sheet

PI-QUAL score	Criteria	Clinical implications
1	All mpMRI sequences are below the minimum standard of diagnostic quality	It is NOT possible to rule in all significant lesions § It is NOT possible to rule out all significant lesions §
2	Only one mpMRI sequence is of acceptable diagnostic quality	
3	At least two mpMRI sequences taken together are of diagnostic quality	It is possible to rule in all significant lesions It is NOT possible to rule out all significant lesions
4	Two or more mpMRI sequences are independently of diagnostic quality	
5	All mpMRI sequences are of optimal diagnostic quality	It is possible to rule in all significant lesions It is possible to rule out all significant lesions

§ Therefore reports should not include PI-RADS or Likert scores

Please (✓) if present: (note: 'adequate' means compliant with the technical specifications reported in PI-RADS v. 2 guidelines) *

T2-WI	DWI	DCE																																																																										
<table border="1"> <thead> <tr> <th colspan="2">Technical parameters</th> </tr> </thead> <tbody> <tr><td>Axial plane</td><td></td></tr> <tr><td>Sagittal or coronal plane</td><td></td></tr> <tr><td>Adequate field of view</td><td></td></tr> <tr><td>Adequate in-plane resolution</td><td></td></tr> <tr><td>Adequate slice thickness</td><td></td></tr> <tr><td>Z-axis correctly positioned</td><td></td></tr> <tr> <th colspan="2">Visual assessment</th> </tr> <tr><td>Capsule clearly delineated</td><td></td></tr> <tr><td>Seminal vesicles clearly delineated</td><td></td></tr> <tr><td>Ejaculatory ducts clearly delineated</td><td></td></tr> <tr><td>Neurovascular bundles clearly delineated</td><td></td></tr> <tr><td>Sphincter muscle clearly delineated</td><td></td></tr> <tr><td>Absence of artefacts (e.g. movement)</td><td></td></tr> </tbody> </table>	Technical parameters		Axial plane		Sagittal or coronal plane		Adequate field of view		Adequate in-plane resolution		Adequate slice thickness		Z-axis correctly positioned		Visual assessment		Capsule clearly delineated		Seminal vesicles clearly delineated		Ejaculatory ducts clearly delineated		Neurovascular bundles clearly delineated		Sphincter muscle clearly delineated		Absence of artefacts (e.g. movement)		<table border="1"> <thead> <tr> <th colspan="2">Technical parameters</th> </tr> </thead> <tbody> <tr><td>Axial plane matching T2-WI</td><td></td></tr> <tr><td>Adequate field of view</td><td></td></tr> <tr><td>Adequate in-plane resolution</td><td></td></tr> <tr><td>Adequate slice thickness</td><td></td></tr> <tr><td>Multiple (> 2) b values acquired</td><td></td></tr> <tr><td>High b value (synthesised or acquired)</td><td></td></tr> <tr> <th colspan="2">Visual assessment</th> </tr> <tr><td>Adequate ADC map</td><td></td></tr> <tr><td>Absence of artefacts (e.g. rectal air)</td><td></td></tr> </tbody> </table>	Technical parameters		Axial plane matching T2-WI		Adequate field of view		Adequate in-plane resolution		Adequate slice thickness		Multiple (> 2) b values acquired		High b value (synthesised or acquired)		Visual assessment		Adequate ADC map		Absence of artefacts (e.g. rectal air)		<table border="1"> <thead> <tr> <th colspan="2">Technical parameters</th> </tr> </thead> <tbody> <tr><td>Axial plane matching T2-WI</td><td></td></tr> <tr><td>Adequate field of view</td><td></td></tr> <tr><td>Adequate in-plane resolution</td><td></td></tr> <tr><td>Adequate slice thickness</td><td></td></tr> <tr><td>Pre-contrast T1-WI available</td><td></td></tr> <tr><td>Fat suppression/subtraction</td><td></td></tr> <tr><td>Adequate temporal resolution [≤ 10 sec]</td><td></td></tr> <tr><td>Adequate total observation rate [≥ 2min]</td><td></td></tr> <tr> <th colspan="2">Visual assessment</th> </tr> <tr><td>Capsular vessels clearly delineated</td><td></td></tr> <tr><td>Vessels in the Alcock's canal clearly delineated</td><td></td></tr> <tr><td>Absence of artefacts (e.g. movement)</td><td></td></tr> </tbody> </table>	Technical parameters		Axial plane matching T2-WI		Adequate field of view		Adequate in-plane resolution		Adequate slice thickness		Pre-contrast T1-WI available		Fat suppression/subtraction		Adequate temporal resolution [≤ 10 sec]		Adequate total observation rate [≥ 2min]		Visual assessment		Capsular vessels clearly delineated		Vessels in the Alcock's canal clearly delineated		Absence of artefacts (e.g. movement)	
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* Weinreb JC, et al. PI-RADS Prostate Imaging - Reporting and Data System: 2015, Version 2. Eur Urol 2016;69:16–40.

Fig. 2. PI-QUAL scoring sheet for post-teaching scans. Reprinted with permission from Elsevier from Giganti F, Allen C, Emberton M, Moore CM, Kasivisvanathan V, for the PRECISION study group. Prostate Imaging Quality (PI-QUAL): A New Quality Control Scoring System for Multiparametric Magnetic Resonance Imaging of the Prostate from the PRECISION trial. Eur Urol Oncol (2020); 3(5):615–619.

4. Discussion

Our study demonstrated that a dedicated lecture on PI-QUAL improved the ability of in-training radiologists in assessing prostate MRI quality. All participants showed improved accuracy in correctly identifying adequate and inadequate MRI image quality. Dedicated

courses and workshops have been shown to improve performance in the diagnostic and quality assessment with multiple other imaging studies and modalities [21,22]. Previous studies have demonstrated that experienced readers and subspecialist radiologists perform better than inexperienced readers and general radiologists [23–27]. Our study showed that residents and fellows at a higher level of training had both

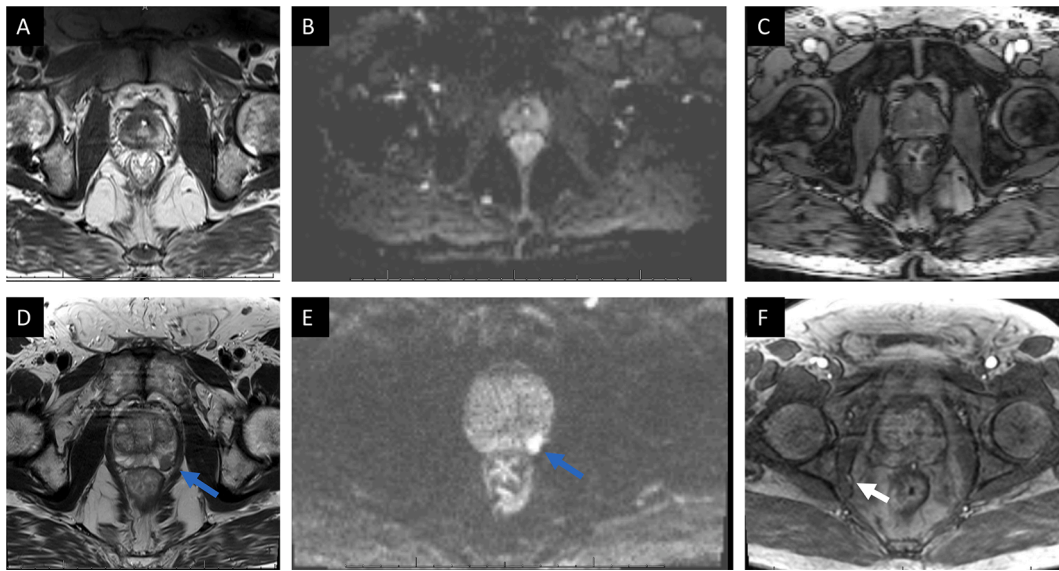


Fig. 3. T2-weighted images (T2-WI), diffusion weighted images (DWI) and dynamic contrast enhanced (DCE) T1-WI of two prostate MRIs, with PI-QUAL scores of 2 (A, B, C) and 4 (D, E, F). T2-WI are of diagnostic quality both in PI-QUAL 2 (A) and PI-QUAL 4 (D) prostate MRI. The DWI (B,E) demonstrates different field-of-view in the two studies and is acceptable only in the PI-QUAL 4 prostate MRI (E). Vessels in the Alcock's canal can be identified on DCE T1-weighted images in the PI-QUAL 4 prostate MRI (white arrow, F), but not in the PI-QUAL 2 prostate MRI (C). Both DCE T1-WI (C,F) are not fat suppressed. As such, only the T2WI is of acceptable diagnostic quality in the PI-QUAL 2 prostate MRI (A), whereas both the T2WI and the DWI are independently of acceptable diagnostic quality in the PI-QUAL 4 prostate MRI (D,E). A PI-RADS 4 lesion can be identified in the left posterior peripheral zone at the midgland of the prostate in the PI-QUAL 4 prostate MRI (arrow in D,E).

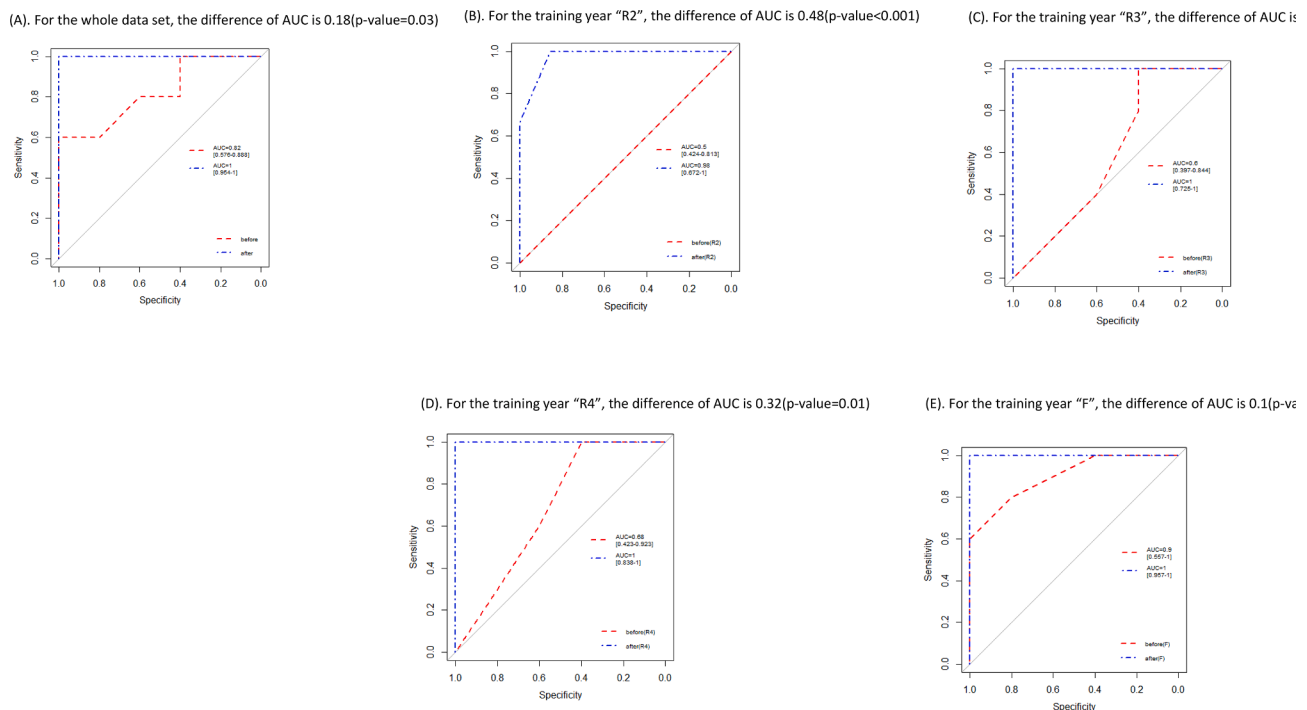


Fig. 4. Average area under the curve (AUC) for the evaluation of image quality in the pre-teaching (blue, dash-dotted line) and post-teaching (red, dashed line) cohorts for the whole dataset (A), for the second- (B), third- (C), fourth-year residents (D) and fellows (E).

higher baseline and post-intervention accuracy than residents with minimal prior exposure to prostate MRI. However, when comparing AUC between different cohorts, residents at a lower levels of training demonstrated increased improvement compared with more experienced residents and fellows. This may be explained by the increased room for growth by inexperienced residents with increased exposure to prostate MRI. Interestingly, there was no significant difference between the pre-

teaching and post-teaching for the fellows' cohort. This can be explained by the relatively high baseline AUC and the small sample size of fellows.

Image quality in prostate MRI is crucial: low quality MRI increases uncertainty in MRI decision-making, decreases the ability of rule-in PCa, and ultimately impacts patients' management [8]. It has already been shown that a dedicated teaching course improves readers' performances in applying PI-QUAL and in assessing the quality of prostate MRI [15]: it

has been shown that accuracy in assessing prostate MRI quality increases after an educational intervention, based on a dedicated lecture and a hands-on-workshop, for a diverse cohort of urologists, radiologists, physicists, and computer scientists [15]. Similarly, we showed that the same applies for in-training-radiologists. Differently from the study by Giganti et al. we used only a dedicated lecture as the educational intervention. We decided that a dedicated lecture, rather than a lecture plus a hands-on-workshop, was sufficient as our cohort of trainees were somewhat familiar with assessing MRI image quality.

We showed that in-training-radiologists with lower level of experience in reading prostate MRI, second year radiology residents, benefited the most from the educational intervention, whereas fellows showed no significant improvement in accuracy after the educational intervention for assessing prostate MRI quality. This is somewhat discordant with what was shown in the study by Giganti et al. [15], where a greater difference in accuracy was found for experienced readers compared to less experienced readers. The reason for this discrepancy is unclear, although radiology fellows in our institution are often at the forefront of assessing the quality of prostate MRI and assessing the need to repeat sequences or repeat the study, and they are familiar with the PI-RADS v2.1 image recommendations, and we can hypothesize that these factors had an impact in their image quality assessment [6,10].

Our study has limitations. It was performed at a single center with a small cohort and a small number of MRI examinations utilizing 3 Tesla MRI scanners from a single vendor which limits generalizability of our results. However, these limitations can be offset in a future meta-analysis aggregating data from multiple institutions to evaluate the effectiveness of a PI-QUAL lecture course. The reference scores were provided by a single experienced reader. Although PI-QUAL has shown strong inter-reader agreement for experienced radiologists [16,17], consensus reference standards in future studies may be better. Additionally, our study had an uneven distribution of PI-QUAL scores. The PI-QUAL scores in our study were predominantly PI-QUAL 3, PI-QUAL 4, and a few PI-QUAL 2. This was not chosen deliberately, but rather as a result from a random selection of patients to produce a realistic distribution of patients. This may have had an impact on assessing the effectiveness of the educational intervention between the different cohorts. However, this provided the benefit of participants providing realistic feedback regarding areas of difficulty utilizing the PI-QUAL scoring system and possible areas of improvement for future iterations.

Although many factors contribute to improving the assessment of prostate MRI quality, our study demonstrated that attending a dedicated PI-QUAL course improves the assessment of prostate MRI quality evaluation for radiologist-in-training. We encourage more widespread use of teaching courses as well as future studies to further evaluate the effectiveness of educational interventions.

Potentially, the PIQUAL system can be incorporated into artificial intelligence software to assure prostate MRI quality. While in the initial phase, this may have to be assessed by a radiologist, automation of quality control will help in real time assessment of quality and reportability, possibly reducing patient call backs for imaging. Further studies may be performed to assess the patient callback rate after incorporating PI-QUAL for real time assessment of prostate MRI quality.

In conclusion, a dedicated course on PI-QUAL can be helpful to improve the assessment of the image quality of prostate MRI for in-training-radiologists.

CRediT authorship contribution statement

Richard Wang: Writing – original draft. **Denver Pinto:** Writing – review & editing. **TianHao Liu:** Formal analysis. **Mohamad Hamade:** Investigation. **Maverick Jubane:** Investigation. **Aazim Arif:** Investigation. **Joseph Boateng:** Investigation. **Sean Maloney:** Investigation. **Ayush Amin:** Investigation. **Jagteshwar Sandhu:** Investigation. **Saad Nini:** Investigation. **John Manov:** Investigation. **Laura Tordjman:** Investigation. **Joseph Villavicencio:** Investigation. **Michelle**

Chamoun: Investigation. **Salman Leslom:** Investigation. **Julietta Aris-tizabal:** Investigation. **Marcelo Felix:** Investigation. **Carolina Gomez-Rodriguez:** Investigation. **Francesco Alessandrino:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Declaration of Competing Interest

Francesco Alessandrino - Subinvestigator, Ascelia Pharma. Other Authors: No conflict of interests.

Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ejrad.2023.110865>.

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