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이중 매개변수 전립선 MRI 품질: 기술적 매개변수에 대한 영향 및 임상적으로 중요한 전립선암의 배제에 미치는 영향

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영문요약

Biparametric Prostate MRI Quality: Influence on Technical Parameters and Impact on Excluding Clinically Significant Prostate Cancer

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Background: To determine technical parameters affecting image quality of biparametric prostate MRI and evaluate the influence of MRI quality on excluding clinically significant prostate cancer (csPCa).

Methods: This retrospective study included patients who underwent prostate MRI in outside imaging facilities and were referred to a tertiary centre between January 2020 and November 2021. Technical parameters of biparametric MRI (T2-weighted image and diffusion-weighted image) were extracted from DICOM header, and their adherence to PI-RADS recommendations was assessed. Biparametric MRI quality was evaluated in terms of the PI-QUAL score as follows: 1, two sequences are below diagnostic quality; 2, only one sequence is acceptable; 3, two sequences are acceptable; and 4, two sequences are optimal by three independent radiologists and dichotomized into below acceptable group and acceptable to optimal group. The association between MRI quality and individual technical parameters or missed csPCa was evaluated. κ statistics were used to evaluate inter-reader agreement of MRI quality assessment.

Results: Among 112 men (mean age ± standard deviation, 66.0 ± 10.0 years) who underwent prostate MRI in 69 different imaging facilities, the adherence rates to technical specifications were variable (57.1−100%). The use of high b value (≥ 1400 s/mm2) and presence of artifact on DWI were associated with image quality (P = 0.003 and < 0.001, respectively). The proportion of missed csPCa was significantly higher in below acceptable quality group than the acceptable to optimal quality group (23.8% vs. 6.6%; P = 0.03). Three readers showed fair to moderate inter-reader agreement in MRI quality assessment (Fleiss κ = 0.393 and pairwise κ = 0.366–0.490).

Conclusions: The use of high b value and reducing artifacts on DWI are significant technical parameters affecting image quality of biparametric prostate MRI. Excluding csPCa may not be possible using low diagnostic quality of prostate MRI.

Keywords: Prostatic cancer; magnetic resonance imaging; MRI quality; PI-QUAL; optimization

목차

표 및 그림 차례

서론

Prostate magnetic resonance imaging (MRI) is important for detection of prostate cancer (PCa) and risk stratification of patients requiring prostate biopsy in the era of MRI-directed PCa diagnosis [1-3]. Although there are clear diagnostic benefits of MRI-directed biopsy pathway as shown in various clinical trials [4-6], those results may not be directly applicable in general practice because of the variability of prostate MRI quality and expertise in MRI reading [2]. In this regard, image optimization and standardization are crucial requirements for the optimal use of MRI-directed PCa diagnosis in lesion detection and characterization. Therefore, reducing variability in MRI quality across vendors and imaging centres is key for the successful use of MRI-directed PCa diagnosis [7].

The Prostate Imaging and Reporting Data System (PI-RADS) documented minimum technical acquisition parameters, such as field-of-view (FOV), in-plane resolution, and the presence of high b values on diffusion-weighted images (DWI) to ensure prostate MRI quality [8, 9]. However, the adherence rates were variable and poor for in-plane resolution on T2-weighted image (T2WI), FOV, and presence of high b values on DWI [10-12]. The influence of technical acquisition parameters on prostate MRI quality has not been determined. Image optimization involving modifications of technical acquisition parameters showed significant prostate MRI quality improvements [13], whereas adherence to those technical acquisition parameters showed no or minimal effect in reducing the variability of prostate MRI [12]. Despite the importance of prostate MRI quality to the diagnostic ability for PCa detection, no generally accepted technical quality criteria encompassing the necessary spatial resolution or signal-to-noise ratio exist [2].

The Prostate Image Quality (PI-QUAL) scoring system was proposed to assess the quality of prostate MRI using objective technical and subjective criteria [14]. It consists of an evaluation of technical acquisition parameters recommended by PI-RADS v2.1 and a subjective assessment of prostate MRI quality [9, 14]. Since its release, several studies have investigated the diagnostic impact of PI-QUAL on PCa and inter-reader agreement [15-18]. According to those studies, low diagnostic quality MRI is associated with an increased proportion of indeterminate MRI results and a higher risk of false-positive referrals and

unnecessary biopsies [16, 17]. However, the diagnostic impact of low diagnostic quality in ruling-in and ruling-out ability of PCa has not been determined.

Therefore, we evaluated the adherence rates of T2WI and DWI of prostate MRI to minimum technical specifications recommended by PI-RADS v2.1 from various imaging institutions and identified the technical parameters related to prostate MRI quality. Because of technical limitations in extracting information, such as temporal resolution and total observation rate of dynamic contrast-enhanced (DCE) imaging from the DICOM header, this study evaluated biparametric MRI. Furthermore, we aimed to evaluate the image quality of biparametric MRIs and assess the diagnostic effect of insufficient diagnostic quality MRI on clinically significant PCa (csPCa).

연구대상 및 연구방법

Study participants

This retrospective study was approved by our institutional review board, and the requirement for informed consent waived because of its retrospective nature. We identified men who underwent prostate MRI at outside imaging facilities and were referred to our tertiary centre for second-opinion reads to determine the necessity of systematic biopsy and/or MRI–transrectal ultrasound (US) fusion-targeted biopsy between January 2020 and November 2021. Images were stored in our PACS and interpreted by one of four genitourinary-specialized radiologists in our institution (with >15-, 13-, 6-, and 3-year experiences in using PI-RADS v2.1). Men without suspicious lesions (PI-RADS score ≥3) on second-opinion reads who did not undergo confirmatory biopsy were excluded, due to lack of reference standards.

Clinical variables (i.e., age and serum prostate-specific antigen [PSA]), type of imaging facilities, magnetic field strength of MRI, PI-RADS score of second-opinion reads, and histopathologic outcomes (i.e., International Society of Urological Pathology category and Gleason score of systematic and/or targeted biopsy) were collected retrospectively from electronic databases, including medical records and radiologic reports. Imaging facilities where images were acquired were classified as university hospital or community-based hospital.

Extraction of acquisition parameters of T2-weighted images and diffusion-weighted images

A minimum of technical parameters for the acquisition of prostate MRI were specified to control prostate MRI quality according to PI-RADS v2.1 [19, 20]. The specified acquisition parameters for T2WI according to the PI-RADS are as follows: (a) same imaging planes with DWI and DCE, (b) in-plane dimension of ≤ 0.7 mm (phase-encoding direction) x ≤ 0.4 mm (frequency-encoding direction), (c) slice thickness of 3 mm, (d) no interslice gap, (e) FOV of 12–20 cm to include the entire prostate gland and seminal vesicles, and (f) at least one additional orthogonal plane (sagittal and/or coronal plane) in addition to the axial plane. Acquisition parameters for DWI are specified as follows: (a) in-plane dimension of ≤

2.5 mm (phase and frequency-encoding directions); (b) slice thickness of ≤ 4 mm; (c) FOV of 16–22 cm; (d) number of b values ≥ 3 with the use of one low b value of 0–100 s/mm2, one intermediate b value at 800–1000 s/mm2, and one high b value); and (e) use of high b value ≥ 1400 s/mm2 [20]. In this regard, acquisition parameters of T2WI and DWI from DICOM headers were extracted, including magnetic field strength. For T2WI, five parameters (i.e., in-plane dimension, slice thickness, presence of interslice gap, FOV, and number of planes) were obtained. For DWI, five parameters (i.e., in-plane dimension, slice thickness, FOV, number of b value, and use of high b value) were obtained. Additionally, the presence of artifacts in each sequence was evaluated by one genitourinary radiologist (K.J.P with a 6-year experience in prostate MRI).

Evaluation of image quality of prostate MRI

The PI-QUAL score, which was developed for the standardization of prostate MRI quality based on multiparametric MRI (T2WI, DWI, and DCE), was used as a reference to evaluate prostate MRI quality in this study [14]. Since our study was based on biparametric MRI, we modified the original PI-QUAL score based on two sequences of T2WI and DWI as follows: 1, all sequences are below the minimum standard for diagnostic quality; 2, only one sequence is acceptable; 3, two sequences are acceptable; and 4, two sequences are of optimal diagnostic quality (Supplementary Table 1). First, the subject image quality of each sequence was evaluated by three independent radiologists (reader 1, reader 2, and reader 3 with 6, 3, and < 1 year experience of prostate MRI, respectively) using a five-point Likert score, as follows: 1, very poor diagnostic quality; 2, poor diagnostic quality; 3, fair diagnostic quality; 4, good diagnostic quality; and 5, excellent diagnostic quality. During image quality analysis, readers evaluated prostate MRI quality with reference to criteria for visual assessment suggested by Giganti et al. [21]. For example, the degree of clear delineation of the capsule, seminal vesicles, ejaculatory ducts, neurovascular bundles, and sphincter muscles, and the presence of artifacts were considered to assign subject image quality score for T2WI. Likewise, the adequacy of ADC map and the presence of artifacts were considered for DWI.

Readers assigned image quality score based on the Likert scale of each sequence using the following criteria: Likert scale 1–2 refers to below the minimum standard of diagnostic quality; Likert scale 3 refers to acceptable; and Likert scale 4–5 refers to optimal diagnostic quality (Supplementary Table 1). According to mPI-QUAL score, prostate MRI quality was dichotomized into below acceptable quality (score 1 and 2) and acceptable to optimal quality (score 3 and 4). The median image quality score of three readers was used for statistical analysis.

Outcome analysis

The results of 12-core systematic and/or MRI–US fusion-targeted biopsy were used for the reference standard. Men with suspicious lesions on MRI (PI-RADS categories 3–5) underwent targeted biopsy using fusion MRI and a transrectal US-guided platform (Artemis, Eigen), followed by 12-core systematic biopsy by one of two operators with 4 and 2 years of experience in MRI–US fusion biopsy, whereas men without suspicious lesions on MRI (PI-RADS categories 1–2) but with suspicion of csPCa underwent systematic biopsy only. CsPCa was defined as a Gleason score $\geq$ 7 (3+4) [19]. Missed csPCa (PCa) were defined in case of (a) a diagnosis of csPCa (PCa) on systematic cores in men without suspicious lesions (PI-RADS category 1−2) or (b) csPCa (PCa) only on systematic cores in men with PI-RADS categories 3–5 with negative results on targeted cores.

Statistical analysis

Adherence rates to each technical parameter were evaluated. Chi-square or Fisher's exact test were used to evaluate the association between adherence of technical parameters and image quality score and between missed rate of PCa or csPCa and image quality score.

Weighted κ and Fleiss's κ statistics were used to assess inter-reader agreement for image quality score. κ statistics were regarded as follows according to Landis and Koch: < 0.20, poor; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, substantial; and 0.81–1.00, almost perfect agreement [22].

Statistical analyses were conducted using the Medcalc software version 14.8.1 (MedCalc Software, Ostend, Belgium) SPSS version 21.0 (IBM). The threshold for statistical significance was set at $P < 0.05$.

연구결과

Patient characteristics

Out of 167 men with outside prostate MRI from 69 different imaging facilities, 55 were excluded due to absence of a confirmatory biopsy, and 112 were included in the study (mean age ± standard deviation [SD], 66.0±10.0; range, 29–87 years and mean PSA ± SD, 8.47±9.46; range, 0.42–87.05) (Figure 1).

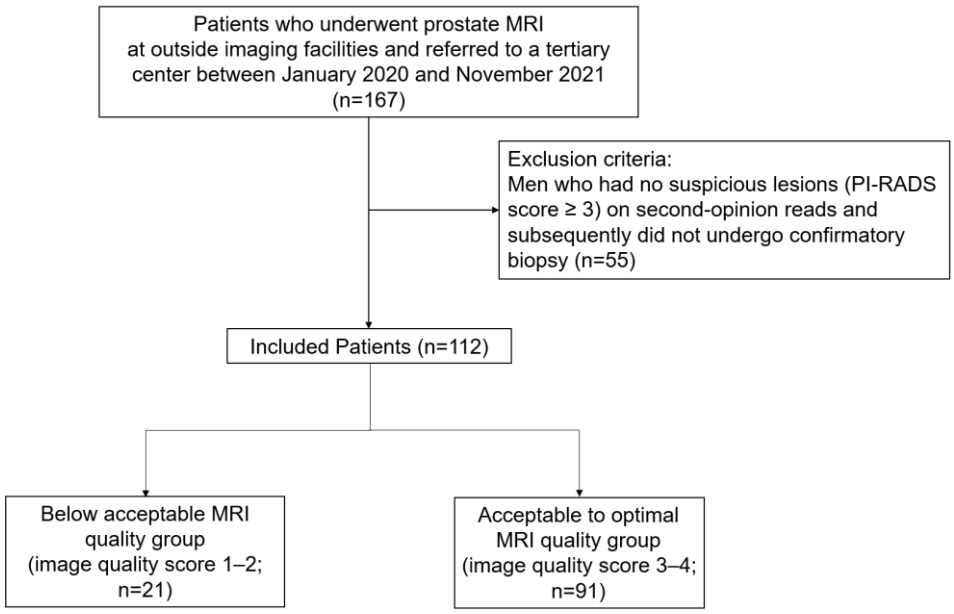

Figure 1. Flow diagram of patient selection.

Of 112 patients, 75 (67.0%) MRI examinations were performed in university hospitals, whereas 37 (33.0%) were acquired in community-based hospitals. Twelve (10.7%) and 100 (89.3%) MRI examinations were performed at 1.5T and 3T, respectively. All examinations were performed without an endorectal coil.

Seventy-two men (64.3%) with PI-RADS categories 3–5 underwent MRI–US fusion-targeted biopsy for suspicious lesions, followed by 12-core systematic biopsy. Conversely, 40 men (35.7%) with PI-RADS categories 1–2 underwent systematic biopsy only. PCa was diagnosed in 63 men (56.3%) and csPCa in 50 men (44.6%). CsPCa was missed in 11 (9.8%) men and PCa was missed in 24 (21.4%) men, respectively. Clinical, MRI, and histopathologic characteristics are summarized in Table 1.

Table 1. Demographics and Characteristics of Included Patients in the Study

Variables	**Value (n=112)**
Age (years)†‡	66.0 ± 10.0 (29–87)
Prostate-specific antigen (ng/mL)†‡	8.47 ± 9.46 (0.42–87.05)
Imaging facilities	
University hospital	75 (67.0)
Community-based hospital	37 (33.0)
Magnetic field strength	
1.5 T	12 (10.7)
3 T	100 (89.3)
PI-RADS score	
1	2 (1.8)
2	38 (33.9)
3	33 (29.5)
4	25 (22.3)
5	14 (12.5)
ISUP category and Gleason score	
Benign	49 (43.8)
1, 6 (3+3)	13 (11.6)
2, 7 (3+4)	23 (20.5)
3, 7 (4+3)	15 (13.4)
4, 8	9 (8.0)
5, 9–10	3 (2.7)
Missed clinically significant prostate cancer	11 (9.8)
Missed prostate cancer	24 (21.4)
Median image quality score	
1	4 (3.6)
2	17 (15.2)
3	47 (42.0)
4	44 (39.3)

Note – Unless otherwise specified, data in parentheses are percentages. ISUP = International Society of Urological Pathology, PI-RADS = Prostate Imaging and Reporting Data System, PI-QUAL score = Prostate Imaging Quality score.

† Data are means ± standard deviation.

‡ Data in parentheses are ranges.

Adherence to acquisition parameters recommended by the PI-RADS guidelines

Acquisition parameters recommended by PI-RADS for T2WI and DWI and adherence rates to acquisition parameters are presented in Table 2 and Supplementary Table 2. Adherence rates to acquisition parameters ranged from 57.1% to 99.1% for T2WI (Table 2); the adherence rate was the lowest (57.1%) in in-plane dimension, followed by no interslice gap (65.2%). Conversely, inclusion of at least one additional orthogonal plane in addition to the axial plane showed the highest adherence rate (99.1%). Among five acquisition parameters for T2WI, 16.1% (18/112) examinations fulfilled all acquisition parameters, followed by 45.5% (51/112) and 17.0% (19/112) meeting the requirements for four and three acquisition parameters, respectively (Supplementary Table 2).

Adherence rates to recommended acquisition parameters were 61.6–100% for DWI; the adherence rate was the lowest (61.6%) for acquisition or calculation of high b value ≥ 1400 s/mm2 and the second lowest (69.6%) for FOV. On the contrary, all MRI examinations (100%) adhered to the requirements of in-plane dimension recommended by PI-RADS (Table 2). Among five acquisition parameters for DWI, 37.5% (42/112) scans met all acquisition parameters, followed by 41.1% (46/112) and 16.1% (18/112) of those who fulfilled four and three acquisition parameters, respectively (Supplementary Table 2).

Artifacts were present in 20.5% (23/112) of T2WIs and 17.9% of DWIs (20/112), respectively.

Association of adherent acquisition parameters and prostate MRI quality

The image quality scores of the median were determined by three independent readers (Table 1 and Supplementary Table 3). According to the median image quality score, 21 men (18.8%) were divided into the below acceptable quality group (mPI-QUAL 1–2), whereas 91 men (81.3%) were classified into the acceptable to optimal quality group (mPI-QUAL 3–4).

The association between adherence to individual acquisition parameters and prostate MRI quality is shown in Table 3. Adherence rate to the inclusion of high b value (≥ 1400 s/mm2) in the acceptable to optimal quality group was significantly higher than that of the below acceptable quality group (adherence rates: 68.1% [62 of 91] vs. 33.3% [7 of 21]; P

= 0.003; Figure 2). Likewise, the absence of artifact on DWI was significantly higher in the acceptable to optimal quality than below acceptable quality group (89.0% [81 of 91] vs. 52.4% [11 of 21]; P < 0.001; Figure 3). However, no other individual acquisition parameters of DWI and T2WI were associated with prostate MRI quality (P ≥ 0.107).

Table 2. Adherence to Acquisition Parameters Recommended by the PI-RADS Guidelines and Presence of Artifacts

Acquisition parameters	Recommendation	Adherence	Non-adherence
T2-weighted imaging			
In-plane dimension	≤ 0.7 mm (phase) x ≤ 0.4 mm (frequency)	64 (57.1)	48 (42.9)
Slice thickness	3 mm	95 (84.8)	17 (15.2)
Interslice gap	No gap	73 (65.2)	39 (34.8)
Field-of-view	12–20 cm	86 (76.8)	26 (23.2)
Number of planes	Axial plane with at least one additional orthogonal plane	111 (99.1)	1 (0.9)
Absence of artifact	No	89 (79.5)	23 (20.5)
Diffusion-weighted imaging			
In-plane dimension	≤ 2.5 mm	112 (100.0)	0 (0.0)
Slice thickness	≤ 4 mm	111 (99.1)	1 (0.9)
Field-of-view	16–22 cm	78 (69.6)	34 (30.4)
Number of *b* value	≥ 3	89 (79.5)	23 (20.5)
High *b* value	≥ 1400 s/mm^2	69 (61.6)	43 (38.4)
Absence of artifact	No	92 (82.1)	20 (17.9)

Note – Data in parentheses are percentages.

Table 3. Adherence Rates to Acquisition Parameters According to the Prostate MRI Quality Group

Acquisition parameters	Below acceptable quality (Score 1–2) (n=21)	Acceptable to optimal quality (Score 3–4) (n=91)	*P* value
T2-weighted images			
In-plane dimension	12 (57.1)	52 (57.1)	>.99
Slice thickness	17 (81.0)	78 (85.7)	0.521
Interslice gap	15 (71.4)	58 (63.7)	0.505
Field-of-view	17 (81.0)	69 (75.8)	0.778
Number of planes	20 (95.2)	91 (100.0)	0.188
Absence of artifact	14 (66.7)	75 (82.4)	0.107
Diffusion-weighted images			
In-plane dimension	21 (100.0)	90 (98.9)	>.99
Slice thickness	21 (100.0)	90 (98.9)	>.99
Field-of-view	15 (71.4)	63 (69.2)	0.843
Number of *b* values	16 (76.2)	73 (80.2)	0.765
High *b* value	7 (33.3)	62 (68.1)	0.003
Absence of artifact	11 (52.4)	81 (89.0)	<.001

Note – Data in parentheses are percentages. mPI-QUAL = modified Prostate Imaging Quality score.

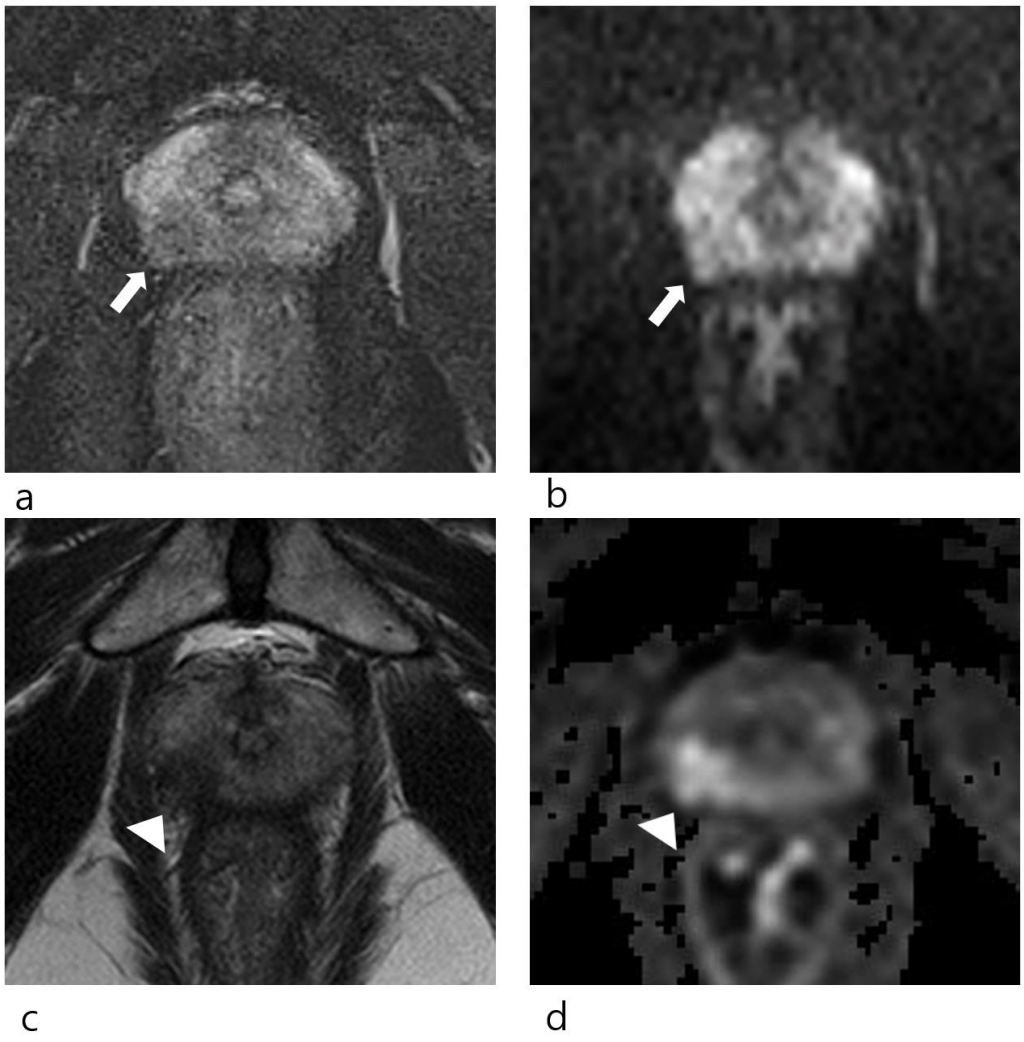

Figure 2. A 67-year-old man who underwent radical prostatectomy for Gleason score 9 (4+5) cancer, which was not detected on the outside prostate MRI. The axial fat-saturated T2-weighted image (a) of the outside MRI demonstrates a suspicious low signal intensity lesion (arrow) in the right peripheral apex. However, this lesion was not clearly seen on diffusion-weighted image (b, the highest b value = 500). The image quality of this outside MRI was rated as mPI-QUAL score 1. This man underwent prostate MRI at a tertiary hospital after 4 months. The axial T2-weighted image (c) shows focal marked hypointense lesion (arrowhead) with corresponding focal diffusion restriction on diffusion-weighted image (d, b value = 1500), which is consistent with PI-RADS 5 lesion.

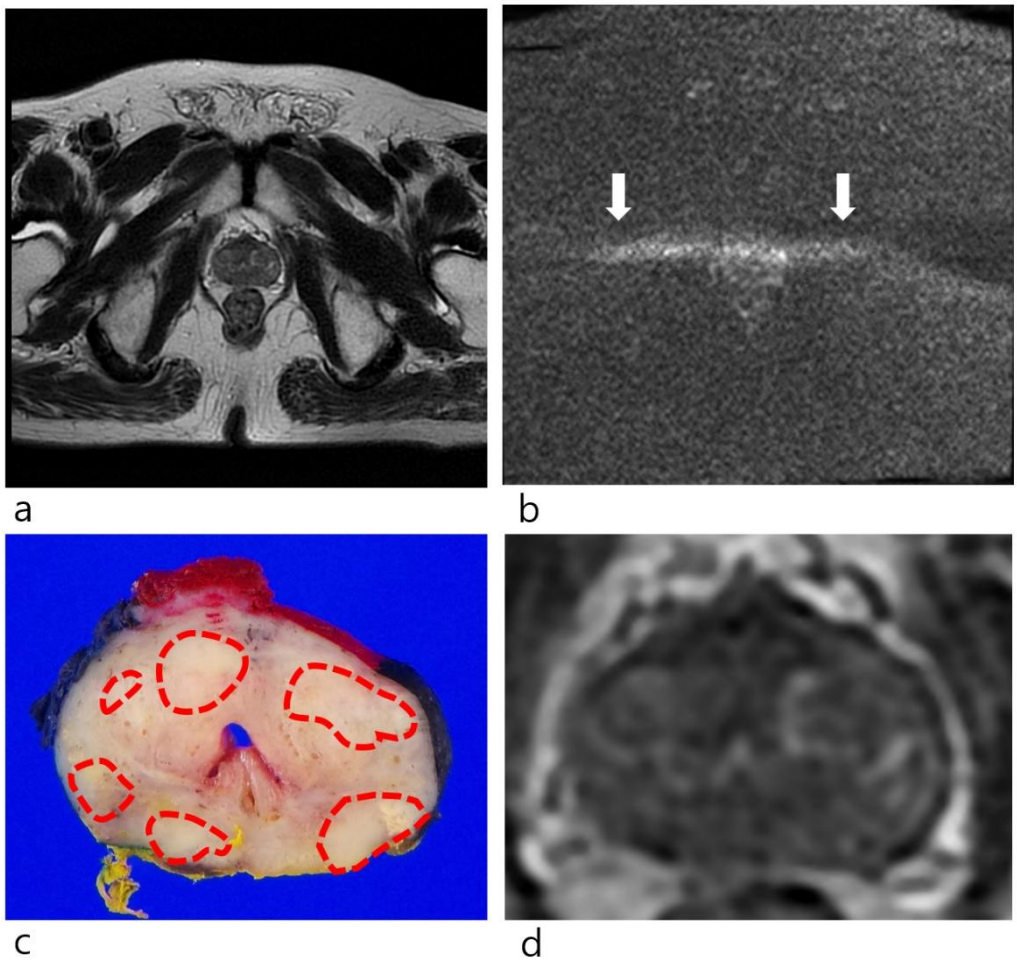

Figure 3. A 76-year-old man who underwent radical prostatectomy for Gleason score 7 (3+4) cancer. The axial T2-weighted image (a) had inadequate field-of-view (FOV of 240 × 240), in-plane dimension (0.94*0.94), and slice thickness (4 mm). Diffusion-weighted image (b) had inadequate number of *b* value (n =1) with artifact (arrow). The prostate MRI quality was rated as image quality score 1. No suspicious lesions were identified on this MRI. This man underwent systematic biopsy due to clinical suspicion of prostate cancer and confirmed as Gleason score 7 (3+4) cancer. Prostatectomy specimen (c) shows multifocal Gleason score 7 (3+4) cancers (outlined by red dashed line), which are not demonstrated on the cor responding slice of T2-weighted image (d).

Relationships between prostate MRI quality and missed csPCa or PCa

The relationships between prostate MRI quality and the proportion of missed PCa or missed csPCa are presented in Table 4. The proportion of missed csPCa in the below acceptable quality group was significantly higher than that of the acceptable to optimal quality group (23.8% vs. 6.6%; P = 0.03; Figure 4). By contrast, the proportion of missed PCa showed no significant differences between the below acceptable quality group and acceptable to optimal quality group (28.6% vs. 19.8%; P = 0.38).

Table 4. Associations Between Prostate MRI Quality and Proportion of Missed Prostate Cancer and Clinically Significant Prostate Cancer

	Below acceptable quality (Score 1–2)	**Acceptable to optimal quality (Score 3–4)**	***P* value**
Missed clinically significant prostate cancer			.031
Missed csPCa	5 (23.8)	6 (6.6)	
Detected csPCa or No csPCa	16 (76.2)	85 (93.4)	
Missed prostate cancer			.376
Missed PCa	6 (28.6)	18 (19.8)	
Detected csPCa or No csPCa	15 (71.4)	73 (80.2)	

Note – Data in parentheses are percentages.

csPCa = clinically significant prostate cancer, PCa = prostate cancer.

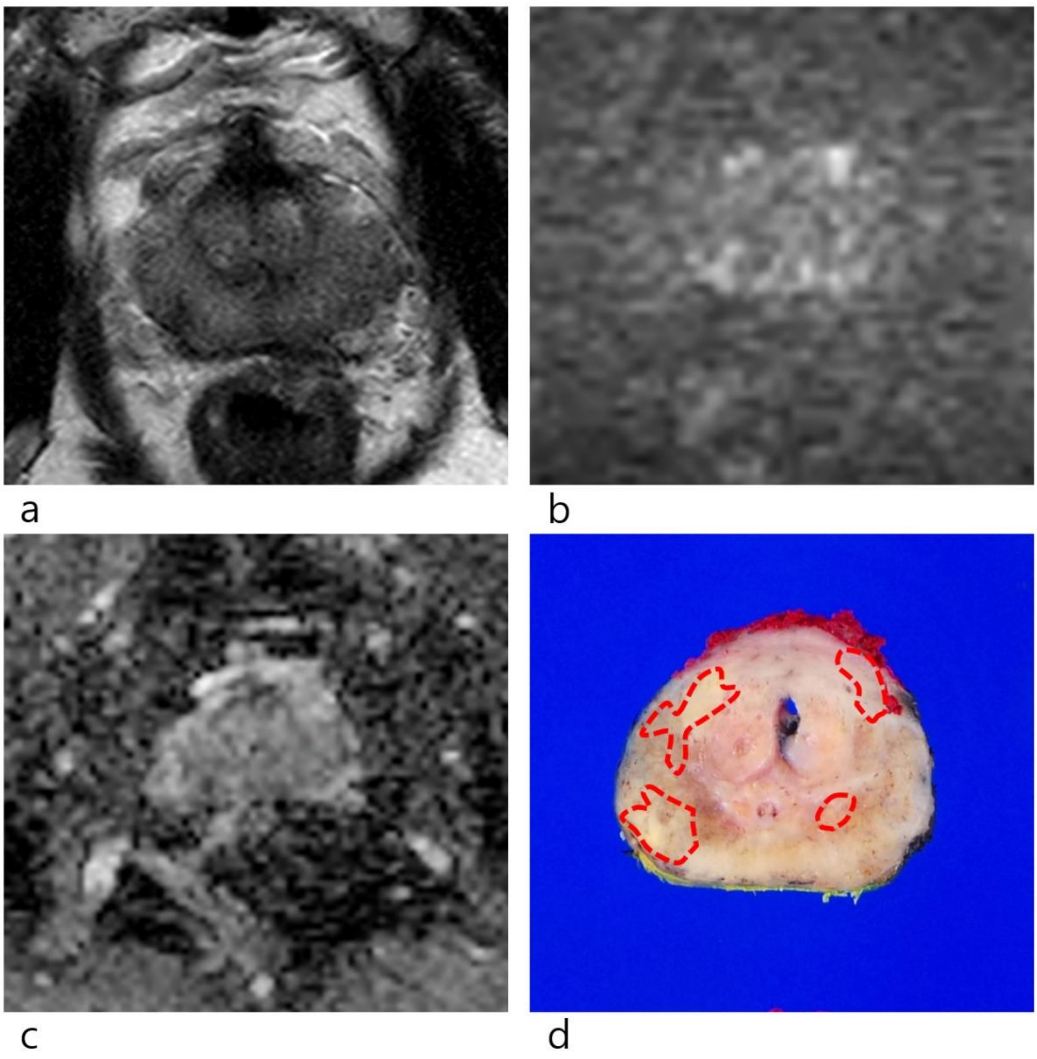

Figure 4. A 59-year-old man who underwent radical prostatectomy for Gleason score 7 (3+4) cancer, which was missed due to poor image quality of the outside prostate MRI. T2-weighted image (a) taken at an outside imaging facility had an inter-slice gap, whereas other technical parameters met the technical specifications. Diffusion-weighted image (b, b value = 1500) and apparent diffusion coefficient (ADC) map (c) met all technical specifications. The median image quality score of MRI was rated as 2 based on subjective image quality assessment. This MRI was interpreted as PI-RADS 2 in the initial radiologic report. Histopathologic specimen (d) shows multiple Gleason score 7 (3+4) prostate cancer lesions, which were missed on MRI.

Inter-reader agreement of image quality assessment

The Fleiss κ value for inter-reader agreement of image quality assessment (below acceptable versus acceptable to optimal) among three readers was fair (Fleiss κ = 0.393). Similarly, pairwise κ values ranged from 0366 to 0.490, indicating fair to moderate agreement.

고찰

Our study demonstrated that the adherence rates to technical acquisition parameters provided by PI-RADS v2.1 were variable (57.1−100%) across imaging facilities. Among technical specifications, adherence to the use of high b value ≥ 1400 s/mm2 and absence of artifact on DWI were associated with the prostate MRI quality scores (P = 0.003 and P < 0.001, respectively). In addition, the MRIs of below acceptable quality were significantly associated with greater likelihood of missed csPCa compared with those of acceptable to optimal quality (23.8% vs. 6.6%; P = 0.03).

Although the prostate MRI quality is a crucial requirement to detect or exclude csPCa on MRI, no standardized tools were available for evaluating image quality. In this regard, the PI-QUAL score has been suggested to evaluate the image quality of the prostate MRI [14], which is based on image quality assessment and adherence to the technical parameters [19, 20]. A few studies have determined the clinical impact of PI-QUAL score in PCa diagnosis [16, 17]. MRI of low diagnostic quality is associated with a decreased proportion of negative MRI calls (PI-RADS score 1 or 2) and an increased proportion of indeterminate MRI calls (PI-RADS score 3) [17]. Additionally, prostate MRI quality influences the subjective confidence level when ruling in and ruling out PCa [17]. Likewise, the prevalence of PCa was significantly lower in patients with low diagnostic quality MRI, indicating a higher risk of false-positive referrals and unnecessary biopsies [16]. Equivalently, this study also validates the limited ability to rule out csPCa in case of MRIs of below acceptable quality. In this regard, low diagnostic quality MRI ultimately leads to more men undergoing biopsy due to a higher proportion of indeterminate MRI reports and impacts the diagnostic performance of MRI-directed PCa diagnosis.

The adherence rates for the acquisition parameters suggested by PI-RADS v2.1 were low in this study. In addition, only 16.1% of MRI scans satisfied all parameters for T2WI, whereas 37.5% of MRIs fulfilled all the required parameters for DWI. A previous study based on 107 imaging facilities in the US also reported low adherence rates to T2WI in-plane dimension (16.8% for frequency-encoding direction and 48.6% for phase-encoding direction), followed by FOV on DWI (30.0%), temporal resolution (31.5%) on DCE, and use of DWI high b value images (58.0%) [10]. Although the adherence rates were higher in

teaching facilities with genitourinary-specialized radiologists and on 3T MRIs, the adherence rates to technical acquisition parameters were not perfect even in those imaging facilities [10, 11]. Considering only two parameters—inclusion of high b value ≥ 1400 s/mm2 and absence of artifact on DWI—were significantly related to prostate MRI quality scores in this present study, reduction and focusing on significant acquisition parameters and subsequent continuous education may be a more effective strategy to improve prostate MRI quality.

The inter-reader agreement of the image quality score was fair to moderate in this study. Similarly, studies using PI-QUAL score demonstrated moderate inter-observer agreement (Cohen's $\kappa = 0.42–0.55$) [16, 23], except for one study that reported almost perfect inter-reader agreement (Cohen's κ of 0.85) between two dedicated radiologists [15]. In this regard, quality assessment systems consisting of subjective criteria can hardly be considered free from variability issues across readers. However, the development and fine modification of a validated system to evaluate MRI quality is crucial to control prostate MRI quality and to achieve optimal diagnostic performance in the detection of csPCa. Notably, education through lectures and a hands-on workshop can improve the performance for assigning and evaluating the PI-QUAL score [24]. Further studies are needed to address the effect of education system to reduce variability among readers for image quality control.

This study has certain limitations. First, it is a nationwide study conducted in single country. The adherence rates to acquisition parameters of prostate MRI across the world would be heterogenous depending on various factors, such as education programs or national quality assurance standards. In addition, this study was based on biparametric MRI, because extraction of temporal resolution or total duration of enhancement on DCE is often limited based on DICOM header information. Therefore, the effect of DCE on overall image quality assessment and diagnostic performance of csPCa might not have been considered.

결론

In conclusion, adherence rates to the minimum technical acquisition requirements are variable across imaging facilities. The use of a high b value of ≥ 1400 s/mm2 and the absence of artifact on DWI are two important acquisition parameters highly related to prostate MRI quality. The image quality of biparametric prostate MRI can affect the diagnostic performance of prostate MRI, especially in ruling out csPCa. Systematic efforts to control MRI image quality and provide continuous education regarding significant imaging parameters with validated quality assessment system are necessary for optimal diagnosis of prostate cancer.

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부록

Supplementary Table 1. Assessment of the Diagnostic Quality of Biparametric MRI Performed in Outside Facilities Using Likert Scales and the Modified PI-QUAL Score

mPI-QUAL score	Criteria
1	All sequences are below the minimum standard for diagnostic quality
2	Only one sequence is of acceptable
3	Two sequences are of acceptable
4	Two sequences are of optimal diagnostic quality

mPI-QUAL: modified Prostate Imaging QUALity.

Supplementary Table 2. Total Adherent Number of Acquisition Parameters

Number of adherent technical parameters	T2WI	DWI
1	4 (3.6)	1 (0.9)
2	20 (17.9)	2 (4.5)
3	19 (17.0)	18 (16.1)
4	51 (45.5)	46 (41.1)
5	18 (16.1)	42 (37.5)

Note – Data in parentheses are percentages. T2WI = T2-weighted imaging, DWI = Diffusion-weighted imaging.

Supplementary Table 3. Modified PI-QUAL Score in Three Independent Readers

mPI-QUAL score	Reader 1	Reader 2	Reader 3
1	9 (8.0)	0 (0.0)	5 (4.5)
2	33 (29.5)	15 (13.4)	12 (10.7)
3	38 (33.9)	48 (42.9)	41 (36.6)
4	32 (28.6)	49 (43.8)	54 (48.2)

Note – Data in parentheses are percentages. mPI-QUAL score = modified Prostate Imaging Quality score.

국문요약

연구제목: 이중 매개변수 전립선 MRI 품질: 기술적 매개변수에 대한 영향 및 임상적으로 중요한 전립선암의 배제에 미치는 영향

연구배경: 이중 매개변수 전립선 MRI의 영상 품질에 영향을 미치는 기술 매개변수를 결정하고 임상적으로 유의한 전립선암(csPCa)을 제외하는 데 있어 MRI 품질의 영향을 평가하고자 한다.

연구방법: 본 연구는 후향적 연구는 외부 영상 센터에서 전립선 MRI를 시행 받고 2020년 1월부터 2021년 11월 사이에 3차 의료센터로 의뢰된 환자들이 포함되었다. DICOM header로부터 이중매개변수 MRI (T2 강조 영상 및 확산 강조 영상)의 기술 매개변수를 추출했으며, PI-RADS 권장사항 준수 여부를 평가하였다. 이중매개변수 MRI 품질은 세 명의 독립적인 영상의학과 의사에 의해 PI-QUAL 점수로 다음과 같이 평가되었고, 이후 허용 미만 그룹과 허용 가능 또는 최적의 그룹으로 이분화 하였다: 1, 두 시퀀스가 진단 품질보다 낮음; 2, 하나의 시퀀스만 허용 가능함; 3, 두 시퀀스가 모두 허용 가능함; 4, 두 개의 시퀀스가 최적임. MRI 품질과 개별 기술 매개변수 또는 놓친 csPCa 간의 연관성을 평가하였다. κ 통계는 MRI 품질 평가의 판독자 간 일치 강도를 평가하는 데 사용되었다.

연구결과: 69개의 서로 다른 영상 센터에서 전립선 MRI를 시행한 112명의 남성(평균 연령 ± 표준 편차, 66.0 ± 10.0세)의 기술 사양 준수율은 다양했다 (57.1–100%). DWI에서 높은 b 값 (≥ 1400 s/mm2)의 사용과 인공물 존재는 이미지 품질과 관련이 있었다 (각각 P = 0.003 및 < 0.001). 놓친 csPCa의 비율은 허용 가능하거나 최적의 품질 그룹보다 허용 가능한 품질 미만 그룹에서 유의미하게 높았다 (23.8% vs. 6.6%; P = 0.03). 3명의 판독의는 MRI 품질 평가에서 중간 정도의 판독의 간 일치 강도를 보였다 (Fleiss κ = 0.393 및 paired κ = 0.366–0.490).

연구결론: DWI에서 높은 b 값을 사용하고 인공물을 줄이는 것은 이중 매개변수 전립선 MRI의 이미지 품질에 영향을 미치는 중요한 기술 매개 변수이다. 전립선 MRI의 낮은 진단 품질로는 csPCa를 제외하는 것이 불가능할 수 있다.