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Prostate Imaging after Focal Ablation (PI-FAB): A Proposal for a Scoring System for Multiparametric MRI of the Prostate After Focal Therapy

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Abstract

At present there is no standardised system for scoring the appearance of the prostate on multiparametric magnetic resonance imaging (MRI) after focal ablation for localised prostate cancer. We propose a novel scoring system, the Prostate Imaging after Focal Ablation (PI-FAB) score, to fill this gap. PI-FAB involves a 3-point scale for rating MRI sequences in sequential order: (1) dynamic contrast-enhanced sequences; (2) diffusion-weighted imaging, split into assessment of the high-*b*-value sequence first and then the apparent diffusion coefficient map; and (3) T2-weighted imaging. It is essential that the pretreatment scan is also available to help with this assessment. We designed PI-FAB using our experience of reading postablation scans over the past 15 years and include details for four representative patients initially treated with high-intensity focus ultrasound at our institution to demonstrate the scoring system. We propose PI-FAB as a standardised method for evaluating prostate MRI scans after treatment with focal ablation. The next step is to evaluate its performance across multiple experienced readers of MRI after focal therapy in a clinical data set.

Patient summary: We propose a scoring system called PI-FAB for assessing the appearance of magnetic resonance imaging scans of the prostate after focal treatment for localised prostate cancer. This will help clinicians in deciding on further follow-up.

Patients with localised prostate cancer can be offered either active surveillance or radical treatment, which can be associated with significant side effects. Focal ablation lies between these two options, with the aim of providing oncological control while preserving erectile and urinary function [1]. The current European Association of Urology

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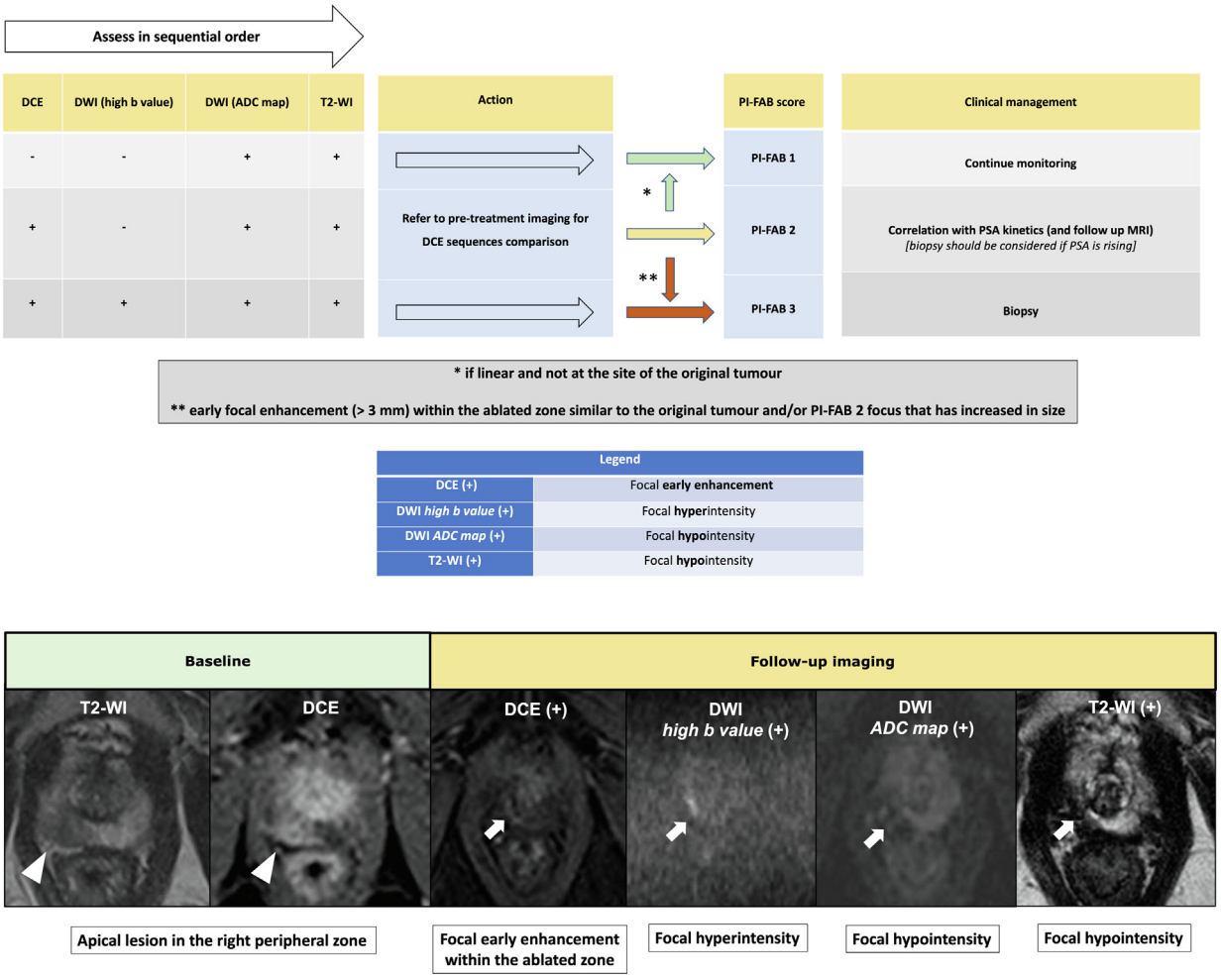

Fig. 1 – Diagram used to assess the likelihood of local recurrence of prostate cancer on multiparametric magnetic resonance imaging after focal ablation using the Prostate Imaging after Focal Ablation (PI-FAB) score. ADC = apparent diffusion coefficient; DCE = dynamic contrast-enhanced; DWI = diffusion-weighted imaging; MRI = magnetic resonance imaging; PSA = prostate-specific antigen; T2-WI = T2-weighted imaging.

position on focal treatment is to offer whole-gland cryotherapy and high-intensity focused ultrasound (HIFU) within a clinical trial setting or well-designed prospective cohort study (strength rating: strong) [2]. In the UK, the National Institute for Health and Care Excellence recommends HIFU for prostate cancer only in specific centres or as part of a clinical trials [3].

At University College London Hospital, we began our HIFU programme in 2004 as a whole-gland intervention and started our focal therapy programme after that. Today, we offer focal HIFU as part of routine care in both primary and salvage settings, concentrating on the treatment of magnetic resonance imaging (MRI)-visible, clinically significant, biopsy-proven prostate cancer of Gleason grade group $\geq$2.

Multiparametric MRI of the prostate plays a key role in focal ablation, both in initial patient selection and throughout follow-up. There is usually a late post-treatment MRI scan after 1 year (although an early scan can be performed at 3–7 days to evaluate the extent of treatment), with subsequent timings of MRI scans adapted according to the initial risk of the disease, prostate-specific antigen (PSA) kinetics (nadir and rate of change), and PSA density changes over time. It is common for scheduled MRI to be performed at 1, 3, 5, 7, and 10 years.

Scoring systems for MRI reporting are widely used for assessment of image quality [4], at first diagnosis [5], in active surveillance [6], for the assessment of extraprostatic extension [7], and for local recurrence after radiation therapy or radical prostatectomy [8], but at present there are no dedicated frameworks for reporting prostate MRI appearance after focal ablation. Here we propose a novel visual scoring system for evaluating multiparametric MRI after focal ablation called PI-FAB (Prostate Imaging after Focal Ablation).

Prostate cancer (both primary and recurrent disease) is often characterised by a low signal on T2-weighted imaging (T2-WI), a high signal on the high-*b*-value sequence associated with a low signal on the apparent diffusion coefficient (ADC) map in diffusion-weighted imaging (DWI), and early enhancement on dynamic contrast-enhanced (DCE) sequences. Imaging following ablation is different and more challenging, as T2-WI and DWI (the dominant sequences according to the Prostate Imaging-Reporting and Data

System [PI-RADS] guidelines) [5] are compromised by the presence of post-treatment fibrosis (low signal on T2-WI and ADC map), and DCE sequences are much more relevant in this setting for lesions in both the peripheral zone and the transition zone.

PI-FAB involves a 3-point scale for assessing the three MRI sequences in sequential order: (1) DCE sequences (the most relevant in this setting); (2) DWI, split into assessment of the high-*b*-value sequence first and then the ADC map; and (3) T2-WI.

A comparison with pretreatment DCE sequences is recommended for all situations, and key information such as the date of treatment, ablation modality, tumour burden (including pretreatment Gleason grade group, maximum cancer core length, and PSA) and post-treatment PSA kinetics should be always provided by the referrer.

Figure 1 shows the procedure used to assess the likelihood of local recurrence of prostate cancer on multiparametric MRI after focal ablation using the PI-FAB score.

Table 1 – PI-FAB scores for four cases illustrating a range of different outcomes

Case	Baseline data			1-yr MRI		2-yr MRI		3-yr MRI		4-yr MRI		5-yr MRI		Outcome
	PSA (ng/ml)	Histology (MCCL)	Lesion location	PI-FAB	Bx	PI-FAB	Bx	PI-FAB	Bx	PI-FAB	Bx	PI-FAB	Bx	
1	5.9	GG 2 (6 mm)	Left PZ	1	–	1	–	1	–	1	–	1 [a]	OOF GG 1 (2 mm)	PSA surveillance
2	4.6	GG 2 (2 mm)	Right PZ	2	–	3	In-field GG 2 (4 mm)	–	–	–	–	–	–	Redo focal HIFU (after MDT review)
3	7.97	GG 3 (9 mm)	Left PZ	2	–	-	–	2	–	–	–	2 [b]	OOF GG 2 (8 mm)	Radiotherapy
4	6.17	GG 2 (9 mm)	Right PZ	1	–	1	–	2	–	2	–	3	In-field GG 2 (5 mm)	RP

MRI = magnetic resonance imaging; PSA = prostate-specific antigen; MCCL = maximum cancer core length; PI-FAB: Prostate Imaging after Focal Ablation; Bx = biopsy; GG: Gleason grade group; PZ = peripheral zone; HIFU = high-intensity focused ultrasound; OOF = out of field; MDT = multidisciplinary team; RP = radical prostatectomy.

[a] Stable PSA.

[b] Rising PSA (from 2.4 ng/ml to 4.4 ng/ml).

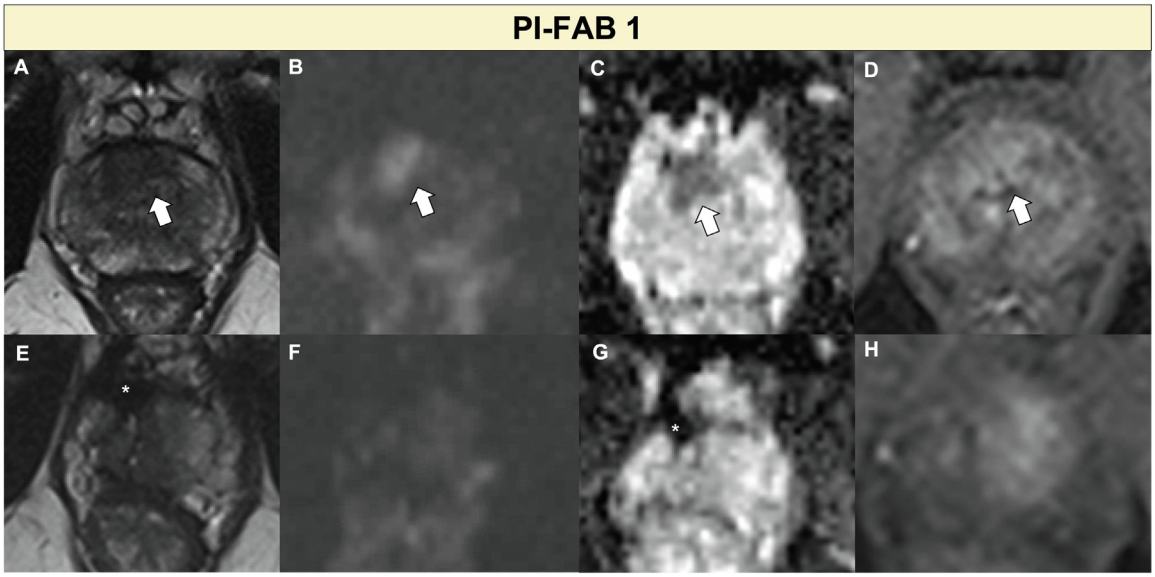

Fig. 2 – Pretreatment (A) axial T2-WI, (B) high-*b*-value, (C) ADC map, and (D) DCE acquisitions show a lesion in the right anterior mid-apical transition zone (arrows; Likert 5/5) treated with high-intensity focused ultrasound. Post-treatment magnetic resonance imaging findings after 5 years show residual fibrosis (asterisks) that is hypointense on (E) T2-WI and (G) the ADC map, with no corresponding hyperintensity on the (F) high-*b*-value and (H) DCE sequences. The Prostate Imaging after Focal Ablation (PI-FAB) score is 1. ADC = apparent diffusion coefficient; DCE = dynamic contrast-enhanced imaging; DWI = diffusion-weighted imaging; MRI = magnetic resonance imaging; T2-WI = T2-weighted imaging.

- Low signal intensity on T2-WI AND low signal intensity on the high-*b*-value sequence AND no enhancement at the site of the original tumour:
  - o PI-FAB 1: likely to represent fibrosis.
- Focal enhancement alone (low signal intensity on T2-WI, low signal intensity on the high-*b*-value sequence):
  - o PI-FAB 1: linear enhancing area AND not at the site of the original tumour or at the edge of the ablation cavity is likely to represent a vessel or inflammation.
  - o PI-FAB 2: enhancing area $\leq$3 mm AND at the site of the original tumour.
  - o PI-FAB 3: early focal enhancement >3 mm within the ablated zone/edge of the ablation cavity OR a PI-FAB 2 focus that has now increased in size.

The choice of a 3-mm threshold is based on our clinical experience.

- High signal intensity on the high-*b*-value sequence AND focal enhancement (any size) AND low signal intensity on T2-WI and on the ADC map:
  - o PI-FAB 3: high suspicion for residual or recurrent disease.

For clinical management decisions, the MRI findings should be considered in conjunction with the whole clinical picture, including PSA kinetics, risk stratification of the original disease, and patient characteristics, including suitability for further focal or radical treatment and patient preference.

For fit patients for whom active treatment is considered, then:

- o PI-FAB 1: continue monitoring.
- o PI-FAB 2: assess PSA kinetics, consider biopsy if PSA is rising, otherwise plan next MRI at 1 year.
- o PI-FAB 3: recommend biopsy.

It should be reiterated that comparison with pretreatment imaging (namely DCE sequences) is crucial, especially for PI-FAB scores of 2 and 3. We note the heterogeneity of strategies to select patients for focal therapy and monitor the untreated prostate. We recommend the untreated prostate should be scored according to standard approaches.

In-field recurrence can only be assessed once the necrosis from the ablation has resolved. If there is still necrosis present, great caution is needed in identifying residual tumour because the background granulation tissue and inflammation can obscure focal recurrence. We acknowledge that a panel of experts has recommended a minimum interval of at least 3 months before performing MRI for local recurrence after radical prostatectomy or radiation therapy [6]. During our experience, we initially performed a 6-month scan after focal therapy, but then changed our routine practice to 12 months if PSA has fallen below the baseline (otherwise an earlier scan is performed at 6 months). Comparison of the 1-year MRI to the early post-treatment

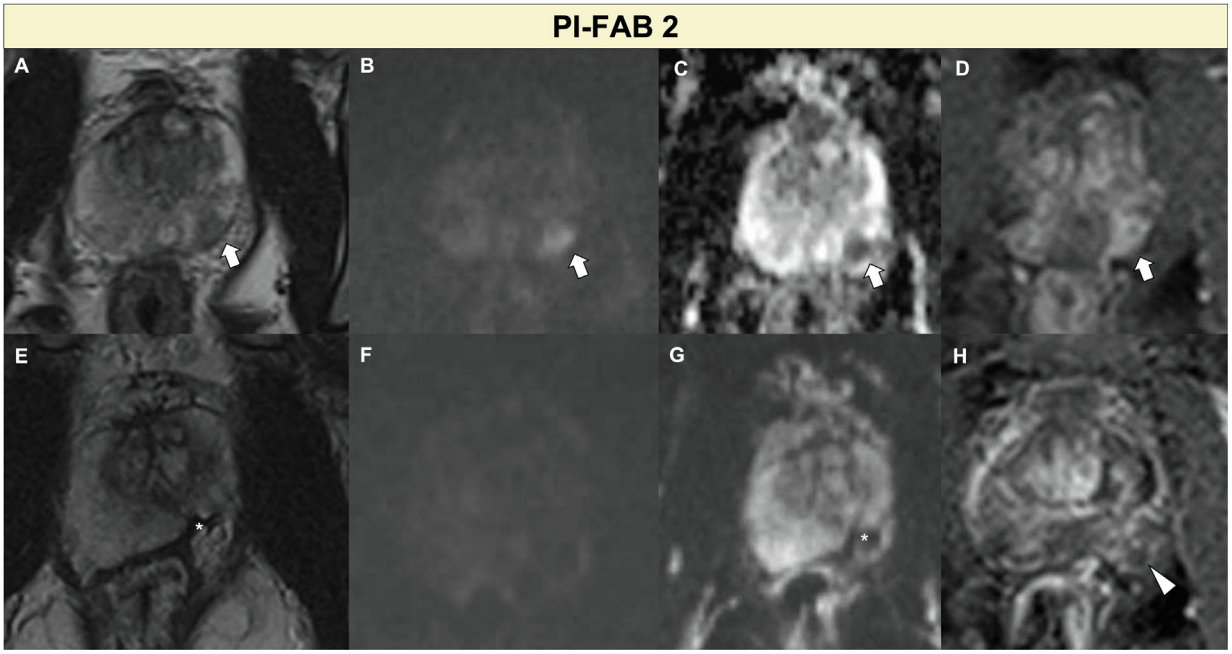

Fig. 3 – Pretreatment (A) axial T2-WI, (B) high-*b*-value, (C) ADC map, and (D) DCE acquisitions show a lesion in the left peripheral zone at the midgland (arrows; Likert 5/5) treated with high-intensity focused ultrasound. Post-treatment magnetic resonance imaging findings after 5 years show residual fibrosis (asterisks) that is hypointense on (E) T2-WI and (G) the ADC map, with (F) no corresponding hyperintensity on the high-*b*-value sequence but (H) mild enhancement (arrowhead) on the DCE sequence. The Prostate Imaging after Focal Ablation (PI-FAB) score is 2. ADC = apparent diffusion coefficient; DCE = dynamic contrast-enhanced imaging; DWI = diffusion-weighted imaging; T2-WI = T2-weighted imaging.

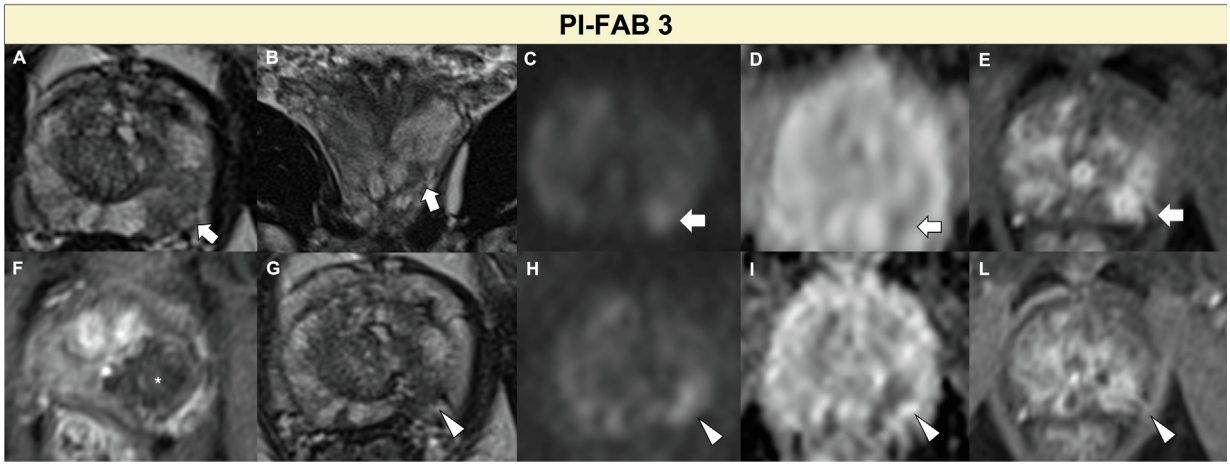

Fig. 4 – Pretreatment (A) axial and (B) coronal T2-WI, (C) high-*b*-value, (D) ADC map, and (E) DCE acquisitions show a lesion in the left peripheral zone at the midgland (arrows; Likert 5/5) treated with high-intensity focused ultrasound. (F) Early post-treatment MRI findings show the necrotic cavity (asterisk) on DCE sequences with adequate coverage. However, following a rise in PSA, MRI after 5 years shows (arrowheads) (G) a focus of low T2 signal, restricted diffusion on (H) the high-*b*-value sequence and (I) the ADC map, and (L) enhancement in the same location as the original tumour. The Prostate Imaging after Focal Ablation (PI-FAB) score is 3. ADC = apparent diffusion coefficient; DCE = dynamic contrast-enhanced imaging; DWI = diffusion-weighted imaging; MRI = magnetic resonance imaging; PSA = prostate-specific antigen; T2-WI = T2-weighted imaging.

scan (3–7 days) can be used to discriminate between residual and recurrent disease, but we acknowledge that not all centres routinely perform early post-treatment MRI.

Table 1 reports four examples of clinical scenarios after focal therapy and related PI-FAB scores assigned by our highly experienced ablation group, which has performed more than 2000 ablations since 2004. Examples of each PI-FAB score are shown in Figures 2–4.

We developed PI-FAB to offer clinicians the first standardised method for evaluating MRI scans after prostate treatment with focal ablation. It should be kept in mind that ascertainment of oncological status following focal therapy on the basis of imaging alone can miss some clinically significant MRI-invisible lesions, although at present it is arguable how clinically relevant such lesions may or may not be in the short term and long term.

The choice of a 3-point scale arises from our experience with other scoring systems (eg, PI-QUAL for prostate MR image quality and PRECISE for radiological changes during active surveillance) [4,6]. Studies have often merged the lowest (ie, PI-QUAL / PRECISE 1 and 2) and the highest (ie, PI-QUAL / PRECISE 4 and 5) scores, as these extreme values usually convey the same message (eg, suboptimal diagnostic quality for PI-QUAL 1 and 2, and radiological progression for PRECISE 4 and 5).

Although there are no specific requirements for prostate MRI after focal treatment, we believe that every study should adhere to the PI-RADS v 2.1 minimal technical recommendations and receive a PI-QUAL score of at least 4 (ie, adequate diagnostic quality) to be able to confidently assess the PI-FAB score.

We plan to apply PI-FAB in our large cohort of patients treated with focal therapy, including HIFU, cryotherapy, irreversible electroporation, and photodynamic therapy, as post-treatment changes are similar for all modalities [9]. We welcome collaboration with other national and international centres performing focal ablation to refine our PI-FAB proposal. Interested individuals can e-mail: f.giganti@ucl.ac.uk or caroline.moore@ucl.ac.uk to discuss this further.

Author contributions: Francesco Giganti had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Giganti, Allen, Moore.
Acquisition of data: Giganti, Allen, Moore.
Analysis and interpretation of data: Giganti, Allen, Moore.
Drafting of the manuscript: Giganti, Allen, Moore.
Critical revision of the manuscript for important intellectual content: Giganti, Dickinson, Orczyk, Haider, Freeman, Emberton, Allen, Moore.
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