Dynamic Contrast-Enhanced MRI for Preoperative Identification of Localised Prostate Cancer

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Abstract

Objectives: To assess the value of pelvic-phased array (PPA) dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) in predicting intraprostatic tumour location and volume for clinically localised prostate cancers.

Methods: Suspicious areas on prospective prebiopsy MRI were located with respect to anatomic features, gland side, and transition zone (TZ) and peripheral zone (PZ) boundaries. These MRI findings were compared with histopathology findings for the radical prostatectomy specimens. Literature review of original studies correlating MRI and histologic results was performed.

Results: DCE-MRI with a PPA is superior to T2-weighted sequences for the detection and depiction of intraprostatic prostate cancer. In a series of 24 cases with 56 separate cancer foci, sensitivity, specificity, and positive and negative predictive values for cancer detection by MRI were, respectively, 77%, 91%, 86%, and 85% for foci >0.2 cc, and 90%, 88%, 77%, and 95% for foci >0.5 cc. Median focus volume was 1.37 cc (range: 0.338–6.32) for foci >0.2 cc detected by MRI in PZ, and 0.503 cc (range: 0.337–1.345) for those not detected by MRI (p < 0.05). The corresponding values for TZ foci were 2.54 (range: 0.75–16.87) and 0.435 (range: 0.26–0.58).

Conclusions: Prebiopsy PPA DCE-MRI is an accurate technique for detecting and quantifying intracapsular TZ or PZ tumour foci >0.2 cc. It has several applications, such as screening for prostate cancer and excluding cancer in patients with a raised PSA level, targeting of biopsies, estimating cancer volume and prognosis, and, in the future, monitoring of disease both during active surveillance and after focal therapy.

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1. Introduction

Preoperative identification of localised prostate cancer for early detection and staging are issues of major concern. Whether the tumour originates in the transition or peripheral zone has important implications regarding detection, prognosis, and therapy [1,2]. Tumour volume, when combined with Gleason differential (or percentage of Gleason 4 and 5), is a powerful predictor of metastasis, although its usefulness in routine clinical practice has not been validated [3,4]. Among the various prostate-imaging modalities, magnetic resonance imaging (MRI) has the potential to improve the identification of prostate cancer at an early stage. A recent review concluded that the addition of dynamic contrast enhancement, spectroscopy, and diffusion-weighted imaging to standard T2-weighted sequences is practical, and has the potential to improve MRI of the prostate to the point at which it has several new applications: the targeting of biopsies, monitoring of disease burden both during active surveillance and after focal therapy, and excluding cancer in patients with a raised prostate-specific antigen (PSA) level [5]. The precise benefit of each technique in a multi-sequence scan remains to be quantified.

To improve MRI identification of localised prostate cancer within the prostate gland, we prospectively investigated the value of dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) with pelvic-phased array (PPA) coils performed before biopsies. PPA coils may represent a valuable alternative to endorectal (ER) coils. PPA coils provide excellent image quality in prostate MRI because of high spatial resolution. These coils offer an excellent signal-to-noise ratio, minimizing distortion and flare artefact [6,7]. We showed that ER and high-resolution PPA coils provide similar prostate-imaging quality and cancer detection rates in T2-weighted sequences at 1.5 T (Puech, personal communication). If we compare our results at 1.5 T with published results at 3 T, we find that our qualitative results for prostate capsule delineation are very similar to those of Sosna et al who used either a single PPA coil or combined ER-PPA coils [8–10], and that our cancer detection performance is very similar to that reported by Kim et al [11]. Our specificity and accuracy are even better, suggesting that 1.5 T prostate imaging remains competitive with 3 T imaging, provided that suitable coils are used.

DCE-MRI is best interpreted with PPA coils. ER coils lead to a loss of signal in the anterior prostate. Unlike PPA coils, ER coils do not provide a homogenous signal, thus preventing accurate DCE. Gland deformation due to the balloon may hinder prostate volume estimation and subsequent data use (eg, for TRUS-guided biopsy with or without image fusion or radiation treatment planning). DCE-MRI with a PPA was reported to be superior to T2-weighted sequences for the detection and depiction of intraprostatic prostate cancer. In one study using DCE-MRI with a PPA, prostate cancer was enhanced

| Table 1 – MRI protocol using a 1.5 T unit† with a dedicated five-element receive-only pelvic-phased array coil** [15] |
|--------------------------------------------------|--------------------|
| Sequences                                      | T2-w turbo spin echo | T1-w gradient echo DCE MRI |
| Protocol                                      | 6 identical sequences of 14 slices every 15 s started immediately after 0.1 mmol/kg IV bolus of gadoteric acid*** at 2 ml/s, followed by 20 ml flush of normal saline**** |
| Slice count and thickness                     | Same as axial T2 sequence |
| Acquisition duration                          | 0.15 per dynamic |
| Anteroposterior                               | No breath holding |
| Field of view                                 | Same as axial T2 sequence |
| 160 × 160 mm                                  | 160 × 160 mm |
| 272 × 231                                      | 128 × 109 |
| 0.59 × 0.71 × 4 mm                            | 1.25 × 1.79 × 4 mm |
| 0.31 × 0.31 × 4 mm                            | 0.31 × 0.31 × 4 mm |
| 85%                                           | 70% |
| Number of repetitions                         | 6 |
| TR/TE                                         | 2 |
| 3200/110 ms                                   | 120/4.6 ms |
| Turbo factor                                  | 16 |
| Flip angle                                    | 50° |

T2-w = T2-weighted; T1-w = T1-weighted; DCE = dynamic contrast-enhanced; MRI = magnetic resonance imaging; IV = intravenous; TR = repetition time; TE = time to echo.
† Intera; Philips Medical System, Best, Netherlands.
** Syn-cardiac coil; Philips Medical Systems.
*** Dotarem; Guerbet, Roissy CdG, France.
**** Spectris SHS 200; Medrad, Indianola, IA, USA.
more and earlier than normal PZ and adenoma, and was well visualised in PZ but not in adenoma [12]. In others studies using DCE-MRI with a PA body coil prior to biopsy, tumours could be precisely located, depicted, and staged [11,13]. Girouin et al [14] showed that DCE-MRI with PPA and simple visual diagnostic criteria is more sensitive for tumour localization than T2-weighted imaging. To assess the accuracy of DCE-MRI in detecting intraprostatic cancer foci, in patients with clinically localised prostate cancer, we compared MRI results with those obtained on pathologic examination of the radical prostatectomy (RP) specimens [15].

2. Materials and methods

2.1. MRI protocol

MRI was performed immediately before transrectal ultrasound (TRUS) biopsy to avoid haemorrhagic and inflammatory lesions that might hinder interpretation of gland signals. (The protocol is described in Table 1.) An axial oblique reference plane perpendicular to the rectal surface of the prostate was used, similar to the sectioning plane of prostatectomy specimens according to the Stanford technique (Fig. 1). MRI findings from 24 patients with biopsy-proven cancer were classified as suspicious if the sum of the subscores was 3, 4, or 5, and not suspicious if the sum was 0, 1, or 2. The zone of origin of each suspicious area was determined by locating the area in relation to the TZ boundary. These MRI findings were compared with histopathology findings for the RP specimens.

3. Results

Histopathology maps of the 24 patients detected 56 separate cancer foci. The largest tumour focus was located in PZ in 14 patients and in TZ in 10 patients. T1-weighted DCE-MRI identified 30 of the 39 tumour foci >0.2 cc and 27 of the 30 foci >0.5 cc. T2-weighted sequences were suspicious in 22 of 30 foci >0.2 cc identified by T1-weighted DCE-MRI sequences. Sensitivity, specificity, and positive and negative predictive values for cancer detection by MRI were, respectively, 77%, 91%, 86%, and 85% for foci >0.2 cc, and 90%, 88%, 77%, and 95% for foci >0.5 cc. Median focus volume was 1.37 cc (0.338–6.32) for foci >0.2 cc detected by MRI in PZ, and 0.503 cc (0.337–0.58) for those not detected by MRI (p < 0.05). The corresponding values for TZ foci were 2.54 (0.75–16.87) and 0.435 (0.26–0.58). MRI results of six cases from our current series are depicted in Figs. 2–7.

4. Discussion

The results for DCE-MRI with PPA have shown that it is an accurate method for depicting intracapsular...
cancers, especially cancers located in the anterior zone of the prostate. Tumour site (TZ vs. PZ) has important implications for tumour incidence, natural history, detection, prognosis, and treatment [16]. The contours of the tumour foci and their location with respect to the TZ boundary on DCE-MRI were in agreement with the patterns of spread observed in histopathology maps by McNeal and Haillot [17]. Recently, Koppie et al [18] assessed 1290 consecutive open and laparoscopic RPs. A total of 259 patients were in the pure-anterior cancer group; 594 patients were in the pure-posterior cancer group. Anterior cancers have lower Gleason grade and lower rates of extraprostatic extension, yet

![Image](image1.png)

Fig. 2 – Case 1: PSA 7.5 ng/ml, cT2. MRI T2-weighted (A) and DCE T1-weighted (B). Axial sections at midgland showing suspicious area in right PZ (arrow). (A) Low signal intensity; (B) early enhancement at 30 s with high signal intensity. Systematic and targeted biopsies were positive on 10 mm in length for adenocarcinoma (3+4 = 7). PSA = prostate-specific antigen; MRI = magnetic resonance imaging; DCE = dynamic contrast-enhanced; PZ = peripheral zone.

![Image](image2.png)

Fig. 3 – Case 2: PSA 4.5 ng/ml, cT1c. MRI T2-weighted (A) and DCE T1-weighted (B). Axial sections at midgland showing suspicious area in left PZ (arrow). (A) Low signal intensity; (B) early enhancement at 30 s with high signal intensity. Systematic biopsies were negative, and targeted biopsies were positive on 7 and 9 mm in length for adenocarcinoma (3+4 = 7). PSA = prostate-specific antigen; MRI = magnetic resonance imaging; DCE = dynamic contrast-enhanced; PZ = peripheral zone.
patients with anterior tumours have higher overall tumour volumes and higher rates of positive surgical margins. The authors concluded that because current tools for detecting and staging prostate cancer can underestimate the extent of anterior prostate disease, improved methods are needed for localizing and characterizing anterior cancers. Results from different studies, including our study, showed that DCE-MRI is one of the tools that help in preoperative identification of these anterior cancers. It was also confirmed \[19,20\].

ER T2 imaging is considered the best technique for prostate cancer local staging and can be combined with H spectroscopic imaging to improve cancer localization and characterization. However, in a literature review, Kirkham et al \[5\] showed that the few studies that have attempted to quantify the benefit of adding a new technique to standard unenhanced sequences showed an increase of 16% in sensitivity with dynamic contrast-enhanced sequence and similar improvements in either sensitivity or specificity with spectroscopy. Overall, it seems reasonable to hope that an approach using T2 sequences, dynamic contrast enhancement, spectroscopy, and, possibly, diffusion imaging will achieve sensitivity for significant cancers of around

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**Fig. 4** – Case 3: PSA 7.5 ng/ml, cT1c. MRI T2-weighted (A) and DCE T1-weighted (B). Axial sections at apex showing suspicious area anterior to urethra (arrow). (A) No suspicious area; (B) suspicious area with early enhancement at 30 s with high signal intensity. Systematic biopsies were negative, and targeted biopsies were positive on 7 mm in length for adenocarcinoma (3+3 = 6). PSA = prostate-specific antigen; MRI = magnetic resonance imaging; DCE = dynamic contrast-enhanced.

**Fig. 5** – Case 4: PSA 22 ng/ml, cT1c. MRI T2-weighted (A) and DCE T1-weighted (B). Axial sections at midgland showing suspicious area in the right TZ (arrow). (A) No suspicious area; (B) suspicious area with early enhancement at 30 s with high signal intensity. Four of 5 right systematic biopsies were positive on maximum 8 mm in length, and 3 of 3 targeted biopsies were positive on 15 mm in length for adenocarcinoma (4+3 = 7). PSA = prostate-specific antigen; MRI = magnetic resonance imaging; DCE = dynamic contrast-enhanced; TZ = transitional zone.
Fig. 6 – Case 5: PSA 8.6 ng/ml, cT1c. MRI T2-weighted (A) and DCE T1-weighted (B). Whole-mounted section at midgland (C). Axial sections at apex showing suspicious area in the anterior fibromuscular stroma (arrow). (A) Suspicious area; (B) suspicious area with early enhancement at 30 s with high signal intensity. One apex systematic biopsy was positive on 1 mm in length, and one targeted biopsy was positive on 7 mm in length for adenocarcinoma (3+3 = 6). Cancer areas correlated with MRI suspicious areas. PSA = prostate-specific antigen; MRI = magnetic resonance imaging; DCE = dynamic contrast-enhanced.

Fig. 7 – Case 6: PSA 12 ng/ml, cT1c. MRI T2-weighted (A) and DCE T1-weighted (B). Axial sections at apex showing suspicious area anterior to urethra (arrow). (A) No suspicious area; (B) suspicious area with early enhancement at 30 s with high signal intensity. Systematic biopsies were negative, and targeted biopsies were positive on 12 mm in length for adenocarcinoma (3+3 = 6). PSA = prostate-specific antigen; MRI = magnetic resonance imaging; DCE = dynamic contrast-enhanced.
90%, with acceptable specificity. Our results showed that prebiopsy PPA DCE-MRI is an accurate technique for detecting and quantifying intracapsular anterior (TZ) or posterior (PZ) tumour foci > 0.2 cc with a sensitivity and a specificity, respectively, of 77% and 91%. These results suggest that cancers missed would be of limited clinical significance and allow a cautious optimism about the potential adequacy of MRI to exclude cancer in a screening setting. Forty-four prostate cancers were detected by biopsy in a series of 83 patients who had prebiopsy diffusion-weighted imaging and dynamic MRI in combination with T2-weighted imaging. The sensitivity, specificity, accuracy, and area under the receiver operator curve (Az) for the detection of the prostate cancer were 95%, 74%, 86%, and 0.966, respectively. The sensitivity, specificity, and accuracy were significantly better than those of T2-weighted imaging alone [21]. In a series of 46 patients in which DCE-MRI with PPA was correlated against RP specimens, it was shown that, of tumours > 0.3 cc, 50–60% and 78–81% were correctly depicted with T2-weighted and DCE imaging, respectively. For both techniques, the depiction rate of tumours > 0.3 cc was significantly influenced by the Gleason score (most Gleason ≤ 6 tumours were overlooked), but not by the tumour volume [14].

5. Conclusions

Prebiopsy PPA DCE-MRI is an accurate technique for detecting and quantifying intracapsular TZ or PZ tumour foci > 0.2 cc. It has several applications, such as the screening for prostate cancer and excluding cancer in patients with a raised PSA level, targeting of biopsies, estimating cancer volume and prognosis, and, in the future, monitoring of disease both during active surveillance and after focal therapy.

References


