QUANTITATIVE MEASUREMENT OF SIGNAL INTENSITY IN DYNAMIC CONTRAST-ENHANCED MRI FOR TIME–INTENSITY CURVE ANALYSIS IN PROSTATE IMAGING

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ABSTRACT

Dynamic Contrast-Enhanced Magnetic Resonance Imaging (DCE-MRI) is a contrast-based MRI technique used to evaluate tissue perfusion and vascular characteristics, generating time–intensity curves (TIC) that assist in differentiating normal prostate tissue, benign lesions, and malignant tumours. Although DCE-MRI is widely applied in multiparametric prostate imaging, many previous studies have emphasized complex pharmacokinetic modeling, which requires specialized software and computational resources, limiting its feasibility in routine clinical practice. Therefore, this study aimed to quantitatively measure signal intensity changes in prostate DCE-MRI examinations and characterize lesion enhancement patterns using a practical semi-quantitative TIC slope approach. Research method employed a descriptive–analytic quantitative design and was conducted at Pusat Pertamina Hospital, Jakarta, during November–December 2024, involving five prostate patients undergoing DCE-MRI scans using a Philips 3-Tesla MRI system with Gadovist contrast media. Signal intensity values were obtained by placing regions of interest (ROI) within the prostate across 20 dynamic post-contrast phases. Semi-quantitative slope analysis was calculated using the percentage difference between baseline signal intensity (SIinitial) and final signal intensity (SIfinal), enabling classification of enhancement curves into Type I (persistent), Type II (plateau), and Type III (washout). The results demonstrated variability in TIC patterns among patients: one patient exhibited a Type II plateau curve with a slope value of −3.22%, suggesting potential malignant characteristics, while four patients showed Type I persistent enhancement patterns with positive slope values ranging from 12.97% to 46.11%, indicating benign lesion features. These findings highlight that semi-quantitative TIC slope analysis provides useful diagnostic information without reliance on advanced pharmacokinetic processing. In conclusion, quantitative signal intensity measurement combined with TIC assessment offers a practical, reproducible, and clinically relevant approach for evaluating prostate vascularization in routine DCE-MRI examinations, although further studies with larger sample sizes are needed to strengthen diagnostic validation.

Keywords: *DEC-MRI; Signal Intensity, Time–intensity curves, Quantitave measurement, Prostate.*

INTRODUCTION

Magnetic Resonance Imaging (MRI) has the capability to produce multiplanar images with high spatial resolution and is widely used as a diagnostic modality for staging prostate disorders. Multiparametric MRI examinations do not rely on a single imaging sequence; instead, they integrate multiple sequences to provide accurate visualization of anatomical and functional information. The sequences commonly used in prostate MRI include T2-weighted imaging (T2WI), diffusion-weighted imaging (DWI), dynamic contrast-enhanced imaging (DCEI), and magnetic resonance spectroscopy imaging (MRSI) (1).

Dynamic Contrast-Enhanced Magnetic Resonance Imaging (DCE-MRI) is an MRI technique that utilizes gadolinium-based contrast agents to evaluate tissue perfusion and vascularization, and is used for the detection, assessment, and staging of various diseases, including prostate, breast, brain, and liver cancers (2). In recent years, the clinical application of DCE-MRI has expanded to include a variety of neurological disorders; however, fundamentally, DCE-MRI has been developed primarily for tumor evaluation (3).

Tumor assessment using DCE-MRI is performed by observing rapid and intense signal enhancement following contrast agent administration. This enhancement pattern assists in identifying and characterizing tumors, as well as differentiating malignant lesions from normal tissue or other lesion types. Several studies have demonstrated that DCE-MRI is effective in lesion differentiation, characterization, and malignancy staging in breast, musculoskeletal, bladder, and prostate tissues (4).

Malignant tumors on DCE-MRI typically exhibit rapid and strong signal enhancement immediately after contrast injection, followed by a relatively rapid signal washout. This pattern differs from that of normal tissue, which demonstrates slower and more gradual signal enhancement during the initial minutes after contrast administration. By incorporating early-phase enhancement characteristics and morphological criteria, DCE-MRI generally provides higher diagnostic accuracy (5).

This imaging technique visualizes lesion vascularization or blood flow to confirm abnormalities detected on T2-weighted (T2W) and diffusion-weighted (DW) MRI, as well as to depict lesions that may not be visible on other sequences (6). Quantitative analysis of temporal signal changes following contrast administration is performed using the time–

intensity curve (TIC). In prostate DCE-MRI, TIC analysis is applied to evaluate changes in prostate tissue signal intensity after contrast agent injection, thereby aiding in the differentiation between normal prostate tissue, benign prostatic hyperplasia, and prostate cancer (7).

Hemodynamic characteristics in DCE-MRI are determined using TIC analysis, which typically requires more than two minutes to generate the curve through region of interest (ROI) placement within the tumor area during the washout phase, where signal enhancement is considered most suspicious (8)(9). In prostate MRI examinations, accurate timing of signal measurement is a critical factor in DCE-MRI with TIC analysis. Therefore, this study focuses on signal intensity measurement for characterizing TIC patterns derived from prostate MRI examinations.

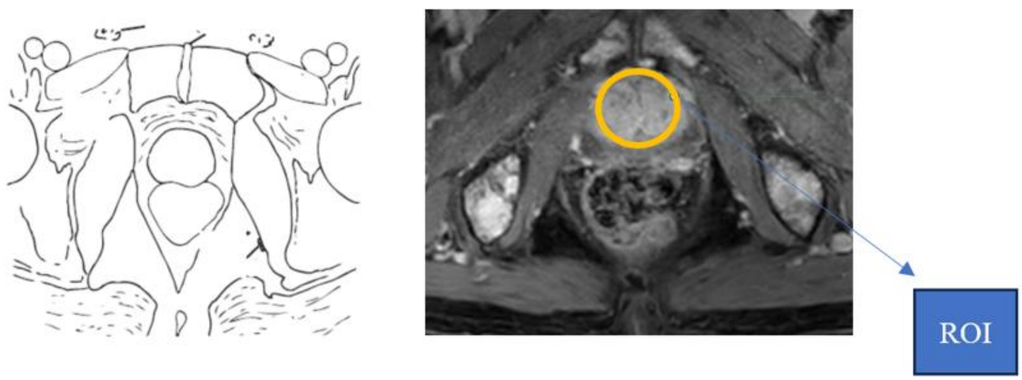
RESEARCH METHOD

The research design employed in this study was a descriptive–analytical design with a quantitative approach, focusing on the measurement of DCE-MRI prostate signal intensity to determine curve characteristics. The study was conducted at Pusat Pertamina Hospital over the period of November–December 2024. The study population consisted of patients who underwent DCE-MRI examinations, with a total sample size of five patients. The sample size was determined based on preliminary considerations during direct observational visits to the hospital.

The research instrument utilized was an MRI system with Philips 3-Tesla specifications equipped with a torso coil, as illustrated in Figure 1. The contrast agent used was Gadovist. The DCE-MRI acquisition parameters are presented in Table 1. After image acquisition and data collection, the initial step involved image processing. Signal intensity measurements were performed by placing regions of interest (ROIs) over the prostate area at multiple time points, as shown in Figure 1. Curve characterization was generated by analyzing changes in signal intensity within prostate tissue following contrast injection, using data obtained from repeated sequential scans.

(a)

(b)



(C)

Figure 1. (a) Philips 3-Tesla MRI system, (b) torso coil, and (c) region of interest (ROI) placement on a prostate DCE-MRI image.

Table.1. Parameters DCE-MRI

Parameters			
Data	**Sagital**	**Coronal**	**Axial**
Sequence	: T2 TSE	: T2 TSE DIXON	: T1 TSE DIXON/ DWI B2400
TE	: 100	: 95	: 11/ 4873
TR	: 3878	: 3046	: 542/ 79
Flip angle	: 90	: 90	: 90
slice	: 30	: 24	: 23/12
Voxel	: 1.00 x 1.00	: 0.6 X1.05	: 0.75 x 0.97/ 2.50 x 2.50

Table 2. DCE-MRI Curve Types

Identification	Description	Signal Difference (%)(10)
Type I – Persistent	The curve demonstrates a continuous and significant increase in signal intensity following contrast agent administration. This pattern is indicative of benign lesions (non-malignant tumors).	>+5
Type II – Plateau	The curve shows an initial peak in signal intensity (plateau) without further significant enhancement. This pattern suggests lesions with potential malignancy.	-5 sampai +5
Type III – Washout	The curve exhibits an initial increase in signal intensity after contrast administration, followed by a rapid decrease (washout). This pattern indicates malignancy (cancerous cells or malignant tumors).	>-5

In the time–intensity curve analysis, the x-axis represents time, while the y-axis represents the ratio between baseline signal intensity and post-contrast signal intensity (SI). In addition, slope analysis was performed to quantify temporal changes in signal intensity, calculated using the following equation (10):

$$\text{SI difference (\%)} = \frac{SI_{\text{final}} - SI_{\text{initial}}}{SI_{\text{initial}}} \times 100$$

where SI_{final} represents the signal intensity at the final time point, and $SI_{initial}$ represents the baseline signal intensity at the onset of contrast enhancement. The determination of SI_{initial} was based on the peak signal intensity increase occurring within the first two minutes following contrast administration. Benign lesions typically exhibit an increasing curve pattern, whereas malignant tumors demonstrate a decreasing signal pattern (11).

Curve analysis involved evaluation of time–concentration curve characteristics to identify abnormal enhancement patterns indicative of tumors or atypical vascular changes, enabling classification of curve types as presented in Table 2 (12) .In addition, an interview was conducted with one MRI radiographer with more than ten years of professional experience to obtain comprehensive information regarding MRI examination procedures and factors influencing DCE-MRI techniques in determining TIC patterns in prostate patients.

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RESULTS AND DISCUSSION

The results of Dynamic Contrast-Enhanced Magnetic Resonance Imaging (DCE-MRI) technique provide detailed information regarding tissue vascularization and permeability, two critical aspects in differentiating benign and malignant prostate lesions. The resulting time–intensity curve (TIC) patterns are classified into three main types: persistent, characterized by continuous signal enhancement; plateau, showing stabilization after an initial increase, and washout, demonstrating a decrease in signal intensity following early enhancement. These patterns reflect underlying blood flow characteristics and tissue permeability, with the washout pattern frequently associated with malignant tissue.

This study analysed five samples selected during DCE-MRI examinations, in which regions of interest (ROIs) were defined across 20 dynamic phases during contrast enhancement. For each phase, sequential changes in signal intensity following contrast agent administration were measured to monitor the dynamic distribution of contrast within prostate tissue, resulting in inter-s9ample variability as illustrated in Figure 2.

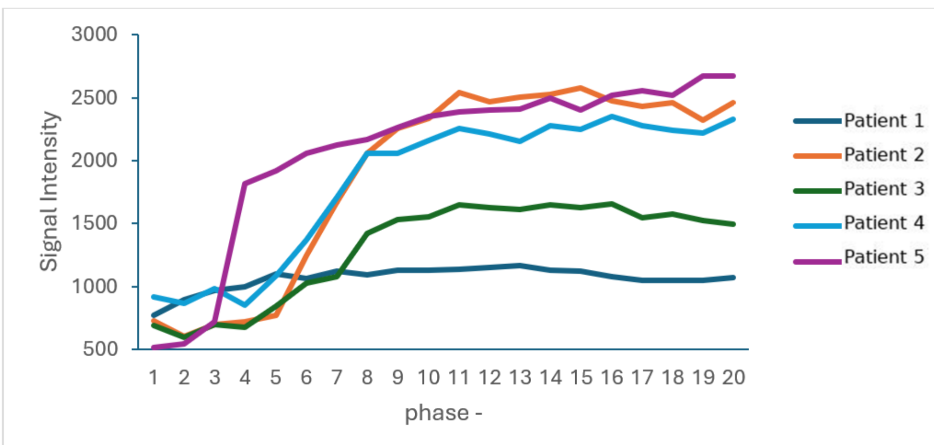

Figure 2. Time–Intensity Curve (TIC) of prostate patients

Furthermore, Table 3 presents the slope percentage data obtained from prostate DCE-MRI examinations. In Patient 1, a slope value of −3.22 was observed, indicating an initial increase in signal intensity followed by a stabilization phase. Accordingly, this curve was classified as Type II (plateau), suggesting malignancy. In Patients 2 through 5, signal intensity differences ranged from 12.97 to 46.11, reflecting an initial increase followed by sustained enhancement. These curves were classified as Type I (persistent), indicative of benign lesions.

Table 3. Signal Intensity Difference Data of Prostate DCE-MRI Patients

Patient	Mean	Standard Deviation	$SI_{initial}$	SI_{final}	Signal Difference (%)
1	1062.06	95.28	1102	1066.5	-3.22
2	1892.93	773.90	2061.5	2463.8	19.51
3	1302.67	396.67	1023.1	1494.9	46.11
4	1829.75	575.06	2060.8	2348.2	12.97
5	2075.28	679.20	2061.3	2679.8	29.71

DCE-MRI has been widely used for prostate lesion characterization through TIC analysis. However, most previous studies have focused on quantitative approaches using pharmacokinetic parameters that require specialized software and substantial computational resources, making them less representative of routine clinical practice. In addition, inconsistencies in TIC patterns among malignant lesions have been reported, as not all malignant tumors exhibit washout curves; some may present plateau or persistent patterns.

This study addresses this gap by applying a semi-quantitative approach based on ROI-based signal intensity measurement and simple TIC slope calculation that is practical, reproducible, and clinically relevant. This approach utilizes empirical data from actual prostate patients and incorporates technical and operational considerations of radiographers, which play a crucial role in the quality and interpretation of DCE-MRI results.

Methods for detecting benign and malignant lesions using DCE-MRI include traditional, semi-quantitative, and semi-automatic approaches (13). In this study, a semi-quantitative method was employed, with lesion areas manually defined using ROI placement to categorize TIC patterns into Type I (persistent), Type II (plateau), and Type III (washout) (14). Stability of signal intensity following initial enhancement reflects moderate blood flow and relatively low capillary permeability (15,16). According to Cao J., variations in the percentage of signal intensity differences represent the slope of the TIC, which occurs due to rapid tumor infiltration during the early phase following contrast agent administration (17).

Although this study successfully categorized TIC patterns in prostate patients, previous studies by Ying Yuan *et al.* and Ohyu *et al.* reported plateau curve patterns in malignant tumors. Therefore, additional diagnostic modalities—such as diagnostic radiology, ultrasonography, and laboratory examinations—are necessary to improve diagnostic accuracy when using DCE-MRI for differentiating benign and malignant lesions (18,19).

Based on interviews with an experienced radiographer, several key challenges were identified in prostate DCE-MRI examinations. One major challenge is maintaining effective communication between radiographers and nurses during contrast injection, which is essential to ensure smooth and timely procedures. Patient cooperation during scanning is also critical, as patient motion can significantly degrade image quality (20,21).

Post-processing presents additional challenges, particularly in DWI image analysis, where radiographers must carefully determine ROI placement to differentiate normal tissue from contrast-enhanced areas. The success of the examination is also highly dependent on accurate timing of contrast injection. Proper timing enables acquisition during the desired contrast phase, ensuring that the resulting data and images meet diagnostic requirements (22). Therefore, effective teamwork, patient cooperation, and precise timing of contrast administration are key elements for successful prostate MRI examinations.

The primary limitation of this study is the small sample size, involving only five patients, which may not adequately represent the broader population. Consequently, the findings should be validated in studies with larger sample sizes. In addition, the analysis was limited to slope parameters and did not include pharmacokinetic parameters such as K_{trans} or V_e , which could provide more comprehensive information for distinguishing between benign and malignant lesions.

CONCLUSION

The results of signal intensity measurements using the dynamic contrast-enhanced MRI (DCE-MRI) technique in five prostate patients demonstrate that this approach can serve as an indicator for evaluating prostate tissue vascularization characteristics. Semi-quantitative analysis of signal intensity changes supports the identification of regions suspected of benign lesions and malignant tumors, thereby contributing to the diagnostic assessment of prostate abnormalities.

REFERENCES

1. Setia Budi W, Choirul Anam dan. Upaya Peningkatan Kualitas Citra Mri Dengan Pemberian Media Kontras. Berkala Fisika . 2013;16(1):9–14.
2. Yan Y, Sun X, Shen B. Contrast agents in dynamic contrast-enhanced magnetic resonance imaging. Oncotarget. 2017;8(26):43491–505.
3. Yoon JM, Choi MH, Lee YJ, Jung SE. Dynamic Contrast-Enhanced MRI of the Prostate: Can Auto-Generated Wash-in Color Map Be Useful in Detecting Focal Lesion Enhancement? Investig Magn Reson Imaging. 2019;23(3):220–7.
4. Tsili AC, Argyropoulou MI, Astrakas LG, Ntoulia EA, Giannakis D, Sofikitis N, et al. Dynamic contrast-enhanced subtraction MRI for characterizing intratesticular mass lesions. American Journal of Roentgenology. 2013;200(3):578–85.
5. Verma S, Turkbey B, Muradyan N, Rajesh A, Cornud F, Haider MA, et al. Overview of dynamic contrast-enhanced MRI in prostate cancer diagnosis and management. American Journal of Roentgenology. 2012;198(6):1277–88.
6. Berman RM, Brown AM, Chang SD, Sankineni S, Kadakia M, Wood BJ, et al. DCE MRI of prostate cancer. Abdominal Radiology. 2016;41(5):844–53.
7. Verma S, Turkbey B, Muradyan N, Rajesh A, Cornud F, Haider MA, et al. Overview of dynamic contrast-enhanced MRI in prostate cancer diagnosis and management. American Journal of Roentgenology. 2012;198(6):1277–88.
8. Cheng L, Li X. Breast magnetic resonance imaging: kinetic curve assessment. Gland Surg. 2013;2(1):50–3.
9. Karavas E, Ece B, Aydın S. Type 2 dynamic curves: A diagnostic dilemma. World J Radiol. 2022;14(7):229–37.
10. El Khouli RH, Macura KJ, Kamel IR, Jacobs MA, Bluemke DA. 3-T dynamic contrast-enhanced MRI of the breast: Pharmacokinetic parameters versus conventional kinetic curve analysis. American Journal of Roentgenology [Internet]. 2011 Dec 20 [cited 2025 Jul 10];197(6):1498–505. Available from: /doi/pdf/10.2214/AJR.10.4665?download=true
11. Li Z, Zhong Y, Wang Y. Exploring Kinetic Curves Features for the Classification of Benign and Malignant Breast Lesions in DCE-MRI. 2024 Apr 22 [cited 2025 Jul 10]; Available from: https://arxiv.org/pdf/2404.13929
12. El Khouli RH, Macura KJ, Jacobs MA, Khalil TH, Kamel IR, Dwyer A, et al. Dynamic contrast-enhanced MRI of the breast: Quantitative method for kinetic curve type assessment. American Journal of Roentgenology. 2009;193(4):295–300.
13. Song YS, Lee IS, Choi YJ, Kim J Il, Choi KU, Kim K, et al. Clinical Efficacy of Ultrafast Dynamic Contrast-Enhanced MRI Using Compressed Sensing in Distinguishing Benign and Malignant Soft-Tissue Tumors. Korean J Radiol [Internet]. 2025 Jan 1 [cited 2025 Jul 10];26(1):43–53. Available from: https://pubmed.ncbi.nlm.nih.gov/39780630/
14. Yin J, Yang J, Jiang Z. Classification of breast mass lesions on dynamic contrast-enhanced magnetic resonance imaging by a computer-assisted diagnosis system based on quantitative analysis. Oncol Lett [Internet]. 2019 Mar 1 [cited 2025 Jul 10];17(3):2623–30. Available from: https://pubmed.ncbi.nlm.nih.gov/30867727/

15. Westbrook Catherine, Talbot John. MRI in practice. 2019 [cited 2025 Jul 10];395. Available from: https://www.wiley.com/en-us/MRI+in+Practice%2C+5th+Edition-p-9781119392002
16. Lavini C, Buiter MS, Maas M. Use of dynamic contrast enhanced time intensity curve shape analysis in MRI: theory and practice. Reports in Medical Imaging [Internet]. 2013 Jul 31 [cited 2025 Jul 10];6(1):71–82. Available from: https://www.dovepress.com/use-of-dynamic-contrast-enhanced-time-intensity-curve-shape-analysis-i-peer-reviewed-fulltext-article-RMI
17. Cao J, Xiao L, He B, Zhang G, Dong J, Wu Y, et al. Diagnostic value of combined diffusion-weighted imaging with dynamic contrast enhancement MRI in differentiating malignant from benign bone lesions. Clin Radiol [Internet]. 2017 Sep 1 [cited 2025 Jul 10];72(9):793.e1-793.e9. Available from: https://pubmed.ncbi.nlm.nih.gov/28545685/
18. Yuan Y, Kuai XP, Chen XS, Tao XF. Assessment of dynamic contrast-enhanced magnetic resonance imaging in the differentiation of malignant from benign orbital masses. Eur J Radiol [Internet]. 2013 Sep [cited 2025 Jul 10];82(9):1506–11. Available from: https://pubmed.ncbi.nlm.nih.gov/23561057/
19. Ohyu S, Tozaki M, Sasaki M, Chiba H, Xiao Q, Fujisawa Y, et al. Combined Use of Texture Features and Morphological Classification Based on Dynamic Contrast-enhanced MR Imaging: Differentiating Benign and Malignant Breast Masses with High Negative Predictive Value. Magnetic Resonance in Medical Sciences [Internet]. 2022 [cited 2025 Jul 10];21(3):485–98. Available from: https://pubmed.ncbi.nlm.nih.gov/34176860/
20. Barentsz JO, Richenberg J, Clements R, Choyke P, Verma S, Villeirs G, et al. ESUR prostate MR guidelines 2012. Eur Radiol [Internet]. 2012 [cited 2025 Jul 8];22(4):746–57. Available from: https://pubmed.ncbi.nlm.nih.gov/22322308/
21. Yin J, Yang J, Jiang Z. Classification of breast mass lesions on dynamic contrast-enhanced magnetic resonance imaging by a computer-assisted diagnosis system based on quantitative analysis. Oncol Lett [Internet]. 2019 Mar 1 [cited 2025 Jul 8];17(3):2623–30. Available from: https://pubmed.ncbi.nlm.nih.gov/30867727/
22. Yuan Y, Yue XH, Tao XF. The diagnostic value of dynamic contrast-enhanced MRI for thyroid tumors. Eur J Radiol [Internet]. 2012 Nov [cited 2025 Jul 10];81(11):3313–8. Available from: https://pubmed.ncbi.nlm.nih.gov/22608396/