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Foreword

A Note from the Editorial Board

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uInnovation is a scientific magazine published by United Imaging Healthcare that has been successfully distributed for over past three years. It aims to serve as a platform for sharing ground-breaking advancements, emerging trends, and future possibilities in the vast expanse that is oncology.

uInnovation is currently in its fourth edition. This year's edition will inform, engage, and inspire you about the latest developments and applications of United Imaging Healthcare. This journal includes quick read sections for those in a rush, and appealing images to promote visual understanding.

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Intravoxel Incoherent Motion MRI for clinical assessment of Prostate and Liver Lesions

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The Diagnostic Gap

Accurate differentiation between malignant and benign lesions in the prostate and liver remains a persistent clinical challenge using conventional imaging methods. Current techniques either lack the sensitivity needed to detect early microstructural changes or depend on contrast agents, which are not suitable for all patients due to safety concerns and increased cost. Such diagnostic uncertainty often leads to delays in diagnosis, repeated imaging, or unnecessary biopsies, thereby increasing patient anxiety and adding to the burden on healthcare systems.

Contrast-enhanced imaging may be contraindicated in certain patient populations (e.g., renal impairment). Imaging workflows often require multiple sequences, leading to inefficiency creating a shortage of non-invasive, cost-effective methods that can offer high diagnostic accuracy.

Clinical challenges

Current diagnostic workflows lack sensitivity to detect microstructural and perfusion-related changes.

Why is sensitivity to microstructural changes important?

i. Microstructural alterations (e.g., changes in cell density, size, and organization) often occur early in disease before gross anatomical changes are visible.
ii. In prostate cancer, increased cellular density and reduced extracellular space preceded detectable tumor growth.
iii. In liver disease, fibrosis, cirrhosis, or malignant transformation alters tissue architecture at a microscopic level.

Why are perfusion-related changes important?

i. Perfusion reflects blood flow characteristics, including capillary density and vascular permeability, are closely tied to tumor angiogenesis and tissue viability.
ii. In prostate cancer, malignant lesions typically demonstrate altered microvascular perfusion compared to benign prostatic hyperplasia (BPH) or normal tissue.
iii. In liver lesions, perfusion characteristics help distinguish hepatocellular carcinoma (HCC), metastases, and benign entities such as hemangiomas or focal nodular hyperplasia (FNH).

Proposed solution: IVIM MRI

To address these diagnostic limitations, Intravoxel Incoherent Motion (IVIM) MRI can be employed. IVIM is a contrast-free technique that separates true molecular diffusion from microvascular perfusion.
IVIM provides three quantitative parameters:

- True diffusion coefficient (D): Reflects tissue cellularity
- Pseudo-diffusion coefficient (D*): Sensitive to microvascular blood flow
- Perfusion fraction (f): Estimates the proportion of perfusion-related signal

Why cannot standard diffusion imaging achieve the same?

Conventional diffusion-weighted imaging (DWI) models the MR signal as a single exponential decay and assumes that all signal changes are purely diffusion-driven. IVIM instead accounts for both molecular diffusion and microvascular perfusion within the same voxel. From a physiological perspective, this distinction is critical: malignant tissues often exhibit restricted diffusion due to increased cellularity, while simultaneously demonstrating altered perfusion caused by tumor angiogenesis and abnormal microvasculature. By separately quantifying these components, IVIM provides a more comprehensive characterization of tissue microenvironment than conventional DWI. Furthermore, IVIM addresses a major limitation of conventional DWI by

separating perfusion-related effects from true diffusion, thereby minimizing the risk of misinterpreting signal changes. This dual assessment adds diagnostic value by enhancing sensitivity to early pathophysiological changes, improving lesion characterization, and offering a non-invasive biomarker for differentiating benign from malignant prostate and liver lesions.

Parameter	Physiological Meaning	Prostate Lesions	Liver Lesions	Clinical Relevance / Key Insight
True Diffusion Coefficient (D)	Reflects tissue cellularity and extracellular space	↓Reduced D in malignancy *Reason*: high cellular density and reduced extracellular space	↓Reduced D in malignant lesions; also low in fibrosis or steatohepatitis due to extracellular matrix deposition	Sensitive to tumor cellularity, but less specific in liver where fibrosis can mimic malignancy
Pseudo-Diffusion Coefficient (D*)	Reflects microvascular flow and capillary architecture	↑Increased D* in malignancy *Reason*: neo- angiogenesis and abnormal micro- vessels	↑Elevated D* in HCC; variable in fibrosis (may decrease due to reduced sinusoidal perfusion)	Highlights perfusion heterogeneity; helpful to distinguish fibrotic vs vascular tumor tissue
Perfusion Fraction (f)	Fraction of signal influenced by microvascular perfusion	Reduced f in malignancy *Reason*: inefficient and disorganized tumor circulation	↓Reduced f in malignancy or fibrosis due to sinusoidal capillary loss	Decreases in both prostate and liver malignancy; reflects impaired microcirculation or loss of normal perfusion network

Methodology and workflow implementation

IVIM MRI is acquired using multi b-value diffusion-weighted sequences, incorporating both very low b-values (e.g., < 200 s/mm²) that are sensitive to perfusion effects and higher b-values that primarily capture molecular diffusion. For accurate modelling, acquisition requires at least one b = 0 image along with four or more non-zero b-values. The IVIM signal attenuation is then expressed by a bi-exponential model:

$$S^b/_{S^0} = (1-f) \times \exp(-bD) + f \times \exp\left[-b \times (D + D^*)\right]$$

where S^b is the signal at a given b-value, S^0 is the signal at b = 0; D is the true molecular diffusion coefficient, D* is the pseudo-diffusion coefficient associated with microvascular perfusion, and f represents the perfusion fraction. Post-processing generally involves nonlinear curve fitting or segmented fitting approaches to derive these quantitative maps, which can then be used for lesion characterization.

In a study with 60 subjects (30 prostate and 30 liver cases) included from two centers, prostate data were acquired at Radiopath Diagnostics, Ranchi, using a 1.5T MR scanner (uMR 580, United Imaging Healthcare Co., Ltd. Shanghai, China), while liver data were obtained at Nova Diagnostics, Astana, Kazakhstan, on the same scanner model. All datasets were processed using United Imaging Healthcare' post-processing platform (MR Diffusion Analysis tool), which is designed to facilitate streamlined integration of IVIM into clinical practice.

The workflow supports the following features:

- Seamless PACS data import
- Automated parameter extraction (D, D*, f)
- One-click lesion ROI propagation across slices
- ROI-based analysis and lesion characterization
- Direct export of quantitative parameter maps for clinical reporting

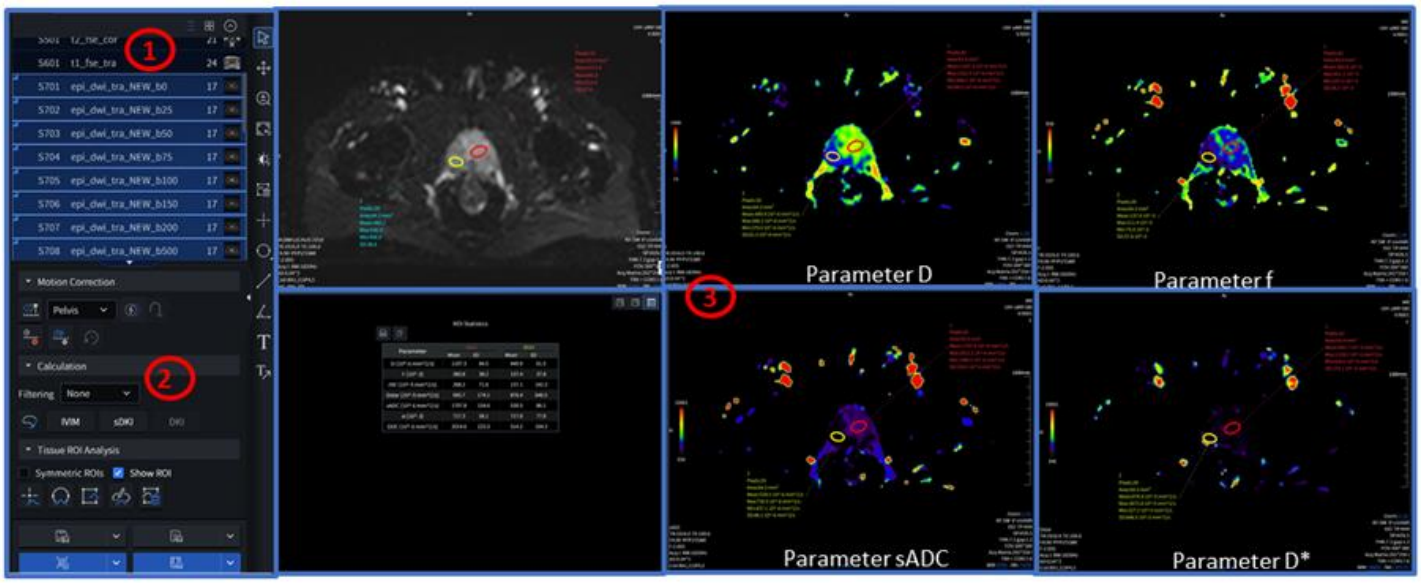

Figure 1: Representative IVIM MRI analysis in a 59-year-old male with a prostate lesion, demonstrating quantitative differences between healthy and malignant tissue regions. The images show manually placed ROIs in healthy peripheral zone (yellow) and lesion (red). Region 1 is study list where exam series can be selected. Region 2 is the control panel optional motion correction, filtering, model fitting, and calculation of parameters. Region 3 is where one can place ROIs, view pseudo-color maps, check statistics and export/push to PACS[#].

[#]The United Imaging Healthcare MR Diffusion Analysis post-processing platform is a non-FDA cleared, and non-CE marked application. This product is not available for the sale in the U.S. for clinical uses.

Key finding:

In the prostate cohort, malignant lesions demonstrated significantly reduced diffusion metrics compared with benign tissues.

- The parameter D was substantially lower in malignant tissues (Mean=0.85; SD=0.23) compared with healthy (Mean=1.20; SD=0.19) and BPH tissues (1.00 ± 0.14, $p < 0.05$).
- The IVIM parameter f of malignant tissues (Mean=0.24; SD=0.06) was also significantly reduced compared with healthy (Mean=0.31; SD=0.07) and BPH tissues (Mean=0.26; SD=0.07).
- In contrast, the pseudo-diffusion coefficient (D*) was significantly higher in malignant tissues (Mean=10.09; SD=4.90) compared with healthy (Mean=8.37; SD=5.41) and BPH tissues (Mean=9.40; SD=5.41).

In the liver dataset, malignant lesions showed marked alterations in perfusion-related parameters.

- The mean f was moderately reduced in malignant lesions (Mean=15.80; SD=3.20) compared with healthy liver tissue (Mean=21.50; SD=4.00, $p < 0.05$).
- The most striking difference was observed in pseudo-diffusion metrics, with malignant lesions demonstrating significantly higher D* values (Mean=4.12; SD=0.45) than healthy lesions (Mean=2.85; SD=0.37, $p < 0.01$), reflecting greater perfusion heterogeneity and microvascular irregularity.
- The parameter D was also substantially lower in malignant tissues (Mean=0.78; SD=0.20) compared with healthy liver tissue (Mean=1.12; SD=0.48, $p < 0.05$).

Takeaway at a glance

IVIM MRI offers a non-invasive, contrast-free, and quantitative method to differentiate benign from malignant lesions in the prostate and liver. By capturing subtle microstructural and perfusion characteristics often overlooked in conventional imaging, it enables more confident and informed clinical decision-making.

Clinical implications

Incorporation of IVIM into routine workflows could lead to:

- Improved diagnostic confidence
- Reduction in unnecessary contrast administration
- Streamlined imaging protocols
- Enhanced patient management and outcomes

As healthcare systems seek efficient, non-invasive diagnostic tools, IVIM stands out as a promising modality ready for broader clinical adoption.

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Dr. Praveen Kumar Tripathi is a consultant radiologist and interventional radiologist based in Ranchi, Jharkhand, and is associated with RadioPath Diagnostic Centre as Head of Radiology and Managing Director. He earned his MD in Radiodiagnosis from the Department of Radiology at SGPGIMS, Lucknow. At Jharkhand Cancer Centre, he serves as a consultant radiologist, contributing his skills in diagnostic and interventional imaging. On professional platforms, he is praised for precise imaging interpretations, a patient-centered approach, and close collaboration with oncologists and other specialists to support cancer diagnosis and treatment in the region.

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