

Proceedings Article

# Accurate Diagnosis of Prostate Cancer via Magnetic-Optical Dual-Modal Imaging Based on Dual-Target Probes

Wenjie Zhao<sup>a,b</sup> · Yu An<sup>a,b,\*</sup>

<sup>a</sup>School of Engineering Medicine & School of Biological Science and Medicine Engineering, Beihang University, Beijing, China

<sup>b</sup>The Key Laboratory of Big Data-Based Precision Medicine (Beihang University), Ministry of Industry and Information Technology of China, Beijing, China

\*Corresponding author, email: [yuan1989@buaa.edu.cn](mailto:yuan1989@buaa.edu.cn)

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## Abstract

The heterogeneous expression of Prostate-Specific Membrane Antigen (PSMA), the primary Prostate Cancer (PCa) biomarker, contributes to significant underdiagnosis. Here, we developed a dual-targeted probe (MNP@FITC-WTN/Dye800CW-D7) against PSMA and Transferrin Receptor (TFR) to enable precise PCa diagnosis. Our probe exhibited enhanced tumor retention and a superior response rate over control groups.

## I. Introduction

As the second most common male cancer [1], prostate cancer (PCa) diagnosis increasingly uses Prostate-Specific Membrane Antigen (PSMA) targeted imaging [2], yet its heterogeneity causes significant false negatives, necessitating invasive biopsy [3]. Magnetic Particle Imaging (MPI) emerges as an ideal tool due to its radiation-free nature, unlimited depth, and high sensitivity [4]. To harness this potential, we engineered a dual-targeted molecular probe. Initial results with MPI and Fluorescence Molecular Imaging (FMI) demonstrate its capability for precise, non-invasive PCa diagnosis.

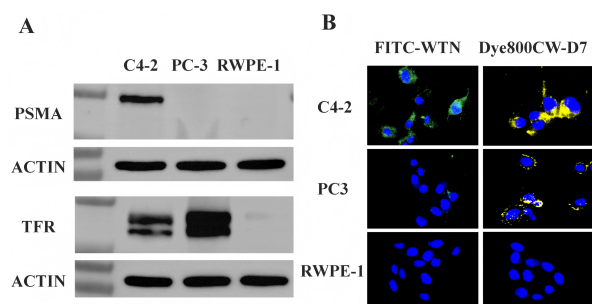
## II. Methods and materials

Expression of PSMA and TFR in cells was detected by Western Blot (WB). The targeting efficacy of high-affinity peptides WTN (FITC-labeled, sequence: WTNHHQH-SKVRE) for PSMA and D7 (Dye800CW-labeled, sequence:

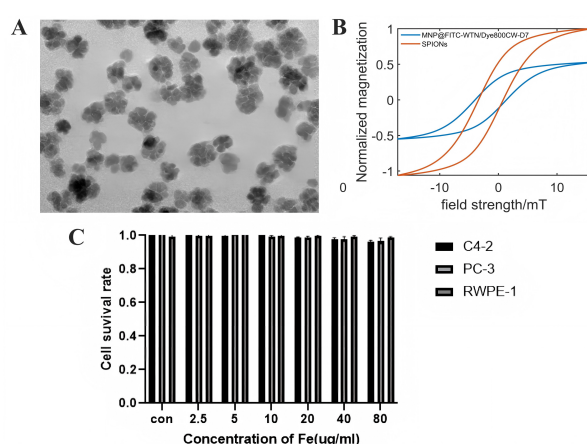
HRPYIAH) for Transferrin Receptor (TFR) was confirmed by confocal microscopy.

We used amide bond reactions to conjugate FITC-WTN and Dye800CW-D7 onto amino-functionalized Synomag nanoparticles. The control group employed non-targeting random peptides with the same relative molecular masses as WTN and D7, with sequences HQHTVRESWKHN (corresponding to WTN) and AYHH-PIR (corresponding to D7).

A subcutaneous PCa mouse model was generated using C4-2 cells. The tumor-bearing mice were randomly divided into four groups, with the MNP@FITC-NC/Dye800CW-NC group serving as the complete negative control. The molecular probes were administered via intratumoral injection. In vivo imaging system (IVIS) and MPI were performed at various time points (pre-injection, 4 h, 8 h, 12 h, 24 h, 2 d, 3 d, and 5 d) to compare the imaging efficacy.



**Figure 1:** (A) Expression of PSMA and TFR in PCa cells (C4-2 and PC3) and normal human prostate epithelial cells (RWPE-1). (B) Binding specificity of FITC-WTN and Dye800CW-D7 peptides to C4-2, PC3, and RWPE-1 cell lines.



**Figure 2:** (A) TEM micrograph of the MNP@FITC-WTN/Dye800CW-D7 probe. (B) Magnetization curve of the synthesized probe. (C) Biosafety assessment of detection probes for the Cell Counting Kit-8 Assay.

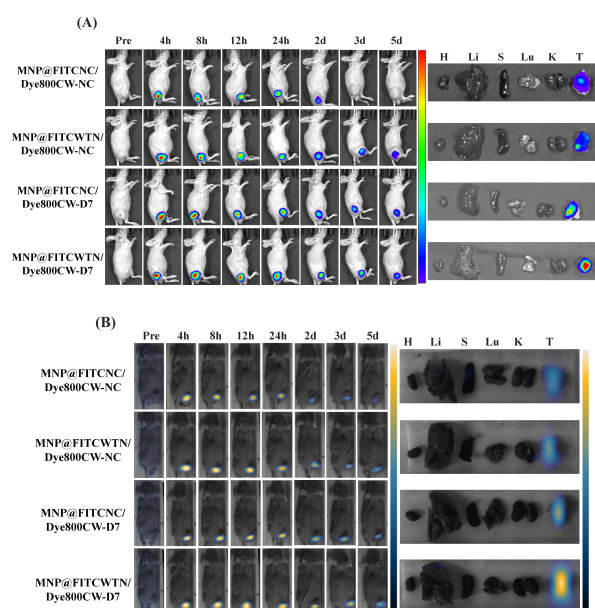
### III. Results and discussion

#### III.I. Analysis of dual-target protein expression and evaluation of targeting peptide specificity

WB results showed upregulated and complementary expression of PSMA and TFR in PCa cells. Correspondingly, both FITC-WTN and Dye800CW-D7 peptides validated this expression profile through their effective binding.

#### III.II. Characterization and biosafety evaluation of the dual-targeted molecular probe

The successful synthesis of the molecular probe MNP@FITC-WTN/Dye800CW-D7 was experimentally confirmed, demonstrating uniform particle size, favorable superparamagnetic properties, and good biocompatibility.



**Figure 3:** (A) Comparative FMI of PCa xenografts using different probe groups. (B) Comparative MPI of PCa xenografts using different probe groups.

#### III.III. Characterization of the synthesized targeted molecular probe

Compared to the control groups, the dual-targeted probe MNP@FITC-WTN/Dye800CW-D7 showed enhanced tumor retention and a notably higher response rate in both FMI and MPI.

### IV. Conclusion

We successfully developed a dual-targeted probe, MNP@FITC-WTN/Dye800CW-D7, with initial results supporting its potential for precise, non-invasive diagnosis of PCa.

Several limitations remain. The subcutaneous xenograft model inadequately recapitulates the tumor microenvironment, necessitating future validation in orthotopic models. The intratumoral injection route does not reflect systemic delivery complexity; thus, tail-vein injection studies are required to assess targeting efficiency. Furthermore, ex vivo probe distribution in major organs in vivo biosafety evaluations are still needed.

Beyond diagnostics, the probe exhibits therapeutic potential. Comprising Synomag particles for magnetic heating and Dye800CW for photothermal conversion, it could enable combined magneto-photothermal therapy of PCa after tumor targeting, laying a foundation for future theranostic applications.

## Acknowledgments

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## Author's statement

**Conflict of interest:** Authors state no conflict of interest.  
**Informed consent:** Informed consent has been obtained from all individuals included in this study.  
**Ethical approval:** The research related to human use complies with all the relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration, and has been approved by the

authors' institutional review board or equivalent committee.

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