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# Development and integrative evaluation of polymer-encapsulated, amine-functionalized iron-based MRI contrast materials

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### Introduction

Iron-based nanoparticles are widely investigated as MRI contrast agents, yet most studies focus on individual materials or single synthesis routes, limiting transferability. Comparative application of standardized characterization and MRI metrics across multiple ferrite platforms is rare. Here, we present an integrative analysis of amine-functionalized ferrite nanoparticles to identify synthesis- and surface-dependent factors that influence MRI signal quality and in vivo behavior beyond material-specific effects.

### Methods

$ZnFe_2O_4$-$NH_2$ and $CuFe_2O_4$-$NH_2$ nanoparticles were synthesized using conventional reflux (12 h) and microwave-assisted solvothermal methods (4 min), enabling direct comparison of synthesis routes. $MnFe_2O_4$-$NH_2$ nanoparticles were prepared via a polyol-based solvothermal approach and subsequently coated with Prussian blue to enhance biocompatibility. All nanoparticle systems were embedded in polyvinylpyrrolidone to ensure colloidal stability and aqueous redispersibility. Structural and physicochemical characterization was performed using HRTEM, XRD, FTIR, and DLS. Magnetic properties were assessed by vibrating sample magnetometry. MRI relaxivity and in vivo imaging performance were evaluated using a small-animal PET/MR system, employing universally accepted MRI metrics.

### Results/Discussion

Synthesis route and surface chemistry influenced colloidal stability and MRI signal behavior. Reflux-synthesized $ZnFe_2O_4$-$NH_2$ showed stable dispersions and homogeneous MRI signal; its microwave-synthesized analogue exhibited sedimentation-induced signal heterogeneity. Microwave $CuFe_2O_4$-$NH_2$ displayed excellent stability, superparamagnetism, and high transverse relaxivity ($r_2$* = 1.50 mL $mg^{-1}$ $ms^{-1}$). Prussian blue–coated $MnFe_2O_4$-$NH_2$ combined reduced cytotoxicity with high $T_2$ relaxivity ($r_2$* = 1.48 mL $mg^{-1}$ $ms^{-1}$). In vivo MRI revealed predominant hepatic accumulation for all systems, consistent with SPION biodistribution. These results demonstrate that signal homogeneity and reliability depend not only on relaxivity but also on synthesis-dependent colloidal behavior, often overlooked in single-material studies.

**Conclusion**

Using universally applicable characterization and MRI metrics, this integrative study demonstrates that synthesis route and surface engineering critically determine MRI signal stability and in vivo performance across ferrite platforms. The findings provide transferable design principles for the rational development of reliable, multifunctional iron-based MRI contrast materials.

**Novelty**

Novel integrative comparison revealing synthesis-dependent MRI signal stability across multiple ferrite platforms using standardized metrics.

**Impact**

Establishes transferable design rules for reliable MRI contrast agent development beyond material-specific optimization.

**Disclosure**

Neither I nor any of my co-authors have any financial interests or relationships to disclose in relation to the subject of this presentation.

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***Keyword***
*MRI contrast agents, ferrite nanoparticles, synthesis optimization, relaxivity, molecular imaging*