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Does Order Matter in Magnetic Hyperthermia? Vesicle Chaining, Particle Heating, and Biological Consequences

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Magnetic nanoparticles (MNPs) are widely investigated for nanomedicine, particularly in cancer therapy via magnetic hyperthermia (MH). In such therapy MNPs are exposed to alternating magnetic fields to generate heat. In the frame of MH, one aspect that has been largely unexplored is the mechanical damage that may arise due to the alignment of MNPs in AC magnetic fields.
Interestingly, when cancer cells are treated with MNPs they accumulate inside vesicles containing a large number of particles. Recent evidence indicates that alternating magnetic fields also induce the chaining of MNP-loaded vesicles inside cells[1], a phenomenon that remains relatively unknown despite its potential impact on heating efficiency and biological outcomes.
We have recently been studying how alternating magnetic field exposure times and field parameters influence vesicle alignment in several cell models. We used ⊠ 13 nm nanoparticles to load intracellular vesicles. Combining fluorescence microscopy and electron microscopy we have been able to determine quantitatively the vesicle organization and the nanoparticle distribution within vesicles. To assess biological consequences, we have evaluated lysosomal alterations induced by MNP-magnetic field interactions. Specifically, we tested whether magnetic stimulation of lysosome-confined MNPs could generate mechanical forces sufficient to disrupt membrane integrity. Our findings reveal that AC magnetic field exposure significantly influences vesicle chaining and may compromise lysosomal stability. These results highlight an underappreciated mechanobiological effect of magnetic hyperthermia that could explain variability in therapeutic outcomes and open new avenues for mechanistically informed nanomedicine design.

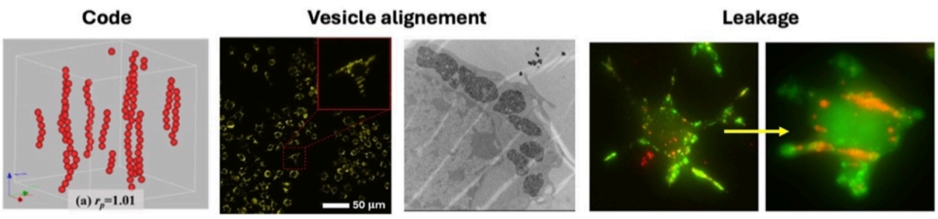

Figure 1: MNPs alignment in colloids, vesicle alignment in cells, and leakage of lysosomal content.

References

[1] Fernández-et al, Advanced Functional Materials 34 (40), 2405334, 2024.

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