ENGINEERING AND CONTROLLING SYNTHETIC AND LIVING MICROROBOTS FOR BIOMEDICAL APPLICATIONS

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Current trends in healthcare are shifting from curative to predictive, personalized, and pre-emptive medicine. Medical microrobots have the potential to drive this transformation by enabling earlier diagnosis, patient stratification, improved treatment administration, and continuous monitorin [1].

In this talk, I will focus on the design and control of microbots to deliver drugs more effectively to targeted diseased sites—a long standing challenge in medicine. Transmitting magnetic fields to guide drug carriers to specific locations is promising, however, current methods often struggle with physiological barriers and are limited to accessible areas.
Here we propose the engineering of magnetic microrobots powered by scalable torque-based actuation via rotational magnetic fields to enhance drug delivery to deep-seated tumors. This approach is particularly effective for microrobots with high anisotropy, which can be boosted by both the shape and magnetocrystallinity of the magnetic materials used. We demonstrate biohybrid microrobots—live bacteria augmented with magnetic nanomaterials—that combine chemotaxis as autonomous navigation with external magnetic control. This hybrid strategy improves tumor targeting compared to unactuated controls [2,3].

Additionally, we have developed synthetic microrobots from biodegradable hydrogels engrafted with patterns of magnetite nanoparticles. By applying dynamic magnetic fields during microfluidic fabrication, we create anisotropic capsule-like microrobots with strings of nanoparticles [4]. These microrobots, actuated with rotational magnetic fields, effectively dissolve thrombi in vascular models and induce convection enhanced drug transport.

Furthermore, on the control side, I will introduce a method for spatially restricting rotating magnetic fields to enhance targeting precision and reduce side effects [5], along with a design integrating inductive feedback for real-time tracking under continuous actuation, enabling closed-loop control [6].

In summary, these advances promise to improve both the detection of diseases and the safety and efficacy of drug delivery, potentially paving the way for microrobots to be integrated into clinical practice.

References

[1] Iacovacci, V., Diller, E., Ahmed, D. & Menciassi, A. Medical Microrobots. *Annu. Rev. Biomed. Eng.* **26**, 561–591 (2024).
[2] Gwisai, T. et al. Magnetic torque-driven living microrobots for increased tumor infiltration. Sci Robot **7**, eabo0665 (2022).
[3] Gwisai, T. et al. Engineering living immunotherapeutic agents for improved cancer treatment. Adv. Ther. (Weinh.) (2023) doi:10.1002/adtp.202300302.
[4] Yan, Y. et al. Programming structural and magnetic anisotropy for tailored interaction and control of soft microrobots. Commun Eng **3**, (2024).
[5] Authors, Journal, Issue (Year) page (Arial 10) Indicate references with sequential numbers within [square brackets].
[6] Authors, Journal, Issue (Year) page (Arial 10) Indicate references with sequential numbers within [square brackets].
[7] Authors, Journal, Issue (Year) page (Arial 10) Indicate references with sequential numbers within [square brackets].

Figures

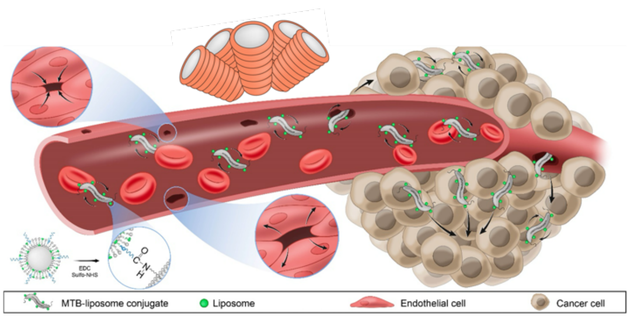

Figure 1. Concept of magnetically controlled biohybrid microrobots for enhanced drug delivery (from [2], Reprinted with permission from AAAS).