32nd URSI GASS, Montreal, 19-26 August 2017

MR-imaging of Physiological Microenvironments using Computer-controlled Magnetotactic Bacteria Labeled with Superparamagnetic Nanoparticles

Sylvain Martel
NanoRobotics Laboratory, Department of Computer and Software Engineering, Institute of Biomedical Engineering
Polytechnique Montréal, Montréal, Canada - sylvain.martel@polymtl.ca

1. Extended Abstract

Iron-oxide superparamagnetic nanoparticles (SPIONs) are widely used as Magnetic Resonance Imaging (MRI) contrast agents. They have been used extensively for imaging the blood vessels of patients using a clinical MRI scanner. In the latter example, the displacement of the SPIONs is directly dependent on the blood flow, restricting the physiological regions where imaging based on MRI contrast agents can be performed. Extending the possible physiological regions to be imaged such as interstitial spaces beyond the reach of such a flow would be possible if such MRI contrast agents could be brought to the regions of interest by transiting through physiological routes such as interstitial spaces characterized by an absence of fluid flow.

To bring such contrast agents to physiological regions of interest for imaging purpose, a displacement force must be provided. Inducing such a force from an exterior magnetic source is not practically feasible as the magnetization volume for nanoparticles is too small to induce sufficient force especially in deep physiological tissues when one considers the fast decay of magnetic field strength with distance from the magnetic source. One potential solution that has been investigated is the use of a sufficiently small self-propelled carrier that can be guided using a weak magnetic torque.

Magnetotactic bacteria cells *Magnetococcus marinus* strain MC-1 [1] have been recently used to transport drug-loaded nanoliposomes in the interstitial spaces (characterized by an absence of flow) of solid tumors in mice [2]. In this example, 70 liposomes were attached per MC-1 cell and guided by a directional magnetic field deep inside the tumoral volume and well beyond the diffusion limit of drifting constructs such as drug molecules or MRI contrast agents. These liposomes can be changed for clusters of iron-oxide superparamagnetic nanoparticles acting as MRI contrast agents. Such new complex made of clusters of SPIONS attached to the surface of each MC-1 cell can allow MR-imaging of physiological microenvironments well beyond the diffusion limits of contrast agents alone.

Directional guidance of these agents self-propelled using their flagella, is achieved by inducing a directional torque from a relatively weak magnetic field on a chain of membranous iron-oxide crystals known as magnetosomes [3] that acts like a microscopic compass needle. A special human-scale interventional platform dubbed the magnetotaxis platform have been developed to provide the 3D magnetic environment suitable to entails these loaded bacteria to migrate towards the physiological regions of interest for therapy or imaging purpose.

2. References

1.D.A. Bazilinski, et al., “Magnetococcus marinus gen. nov., sp. nov., a marine, magnetotactic bacterium that represents a novel lineage (Magnetococcaceae fam. nov., Magnetococcales ord. nov.) at the base of the Alphaproteobacteria,” *Int. J. Syst. Evol. Microbiol.*, **63**, 2013, pp. 801–808.

2.O. Felfoul, M. Mohammadi, S. Taherkhani, D. de Lanauze, Y. Z. Xu, D. Loghin, S. Essa, S. Jancik, D. Houle, M. Lafleur, L. Gaboury, M. Tabrizian, N. Kaou, M. Atkin, T. Vuong, G. Batist, N. Beauchemin, D. Radzioch, S. Martel, “Magneto-aerotactic bacteria deliver drug-containing nanoliposomes in tumour hypoxic regions,” *Nat. Nanotechnol*., **11**, Aug. 2016, pp. 941–947.

3. D. Schüler, “Formation of magnetosomes in magnetotactic bacteria,” J. Molec. Microbiol. Biotechnol. 1, 1999, pp. 79–86.