PULSED MAGNETIC FIELD IMPACT ON LIVING CELLS CONTAINING BIOGENIC MAGNETITE NANOPARTICLES

MICLAUS SIMONA[1*], BARBU-TUDORAN LUCIAN [2], MOISESCU CRISTINA[3], BECHET PAUL [1], DARABANT LAURA[4]

[1]„Nicolae Balcescu" Land Forces Academy, Sibiu, Romania
[2] National Institute R&D for Isotopic and Molecular Technologies, Cluj-Napoca, Romania
[3] Institute of Biology Bucharest, Romanian Academy, Bucharest, Romania
[4] Technical University of Cluj-Napoca, Romania

Abstract: Intense pulsed magnetic fields with frequency components in the kHz-MHz range, produced by a transcranial magnetic stimulation applicator were delivered to samples containing magnetotactic bacteria cells with the aim of observing changes of cellular appearance by scanning-transmission electron microscopy. Cellular integrity was affected in a manner dependent on the magnetic stimulus parameters.

Key-words: pulsed magnetic field, transranial magnetic stimulator, magnetosomes, cell integrity, membrane damage.

1. INTRODUCTION

High intensity pulsed magnetic field (PMF) is produced in the vecinity of coil-probes used in transcranial magnetic stimulation (TMS). Biological material containing magnetic nanoparticles (MNP) may respond to such stimuli in specific ways, insufficiently explored. A significant heating effect was recently reported in magnetite MNP distributed in agarose gel exposed to 1000 biphasic pulses at 60 Hz, delivered by a TMS coil [1], even if the main research on magnetothermal control of neural activity [2] is taking place generally in the frequency range (100 kHz - 1 MHz). PMF delivered by TMS coils to biological material not containing MNPs, has previoulsy indicated that: a) molecular uptake of cells may appear [3]; b) neural cells present specific effects [4]; c) brain stimulation thresholds exist and can be computed [5].
Present experiment aimed at observing few different PMFs influence on the appearance at sub-micrometric scale of liquid suspensions of magnetotactic bacteria cells which contain biogentic magnetite nanoparticles organized in chains (magnetosomes).

2. MATERIALS AND METHODS

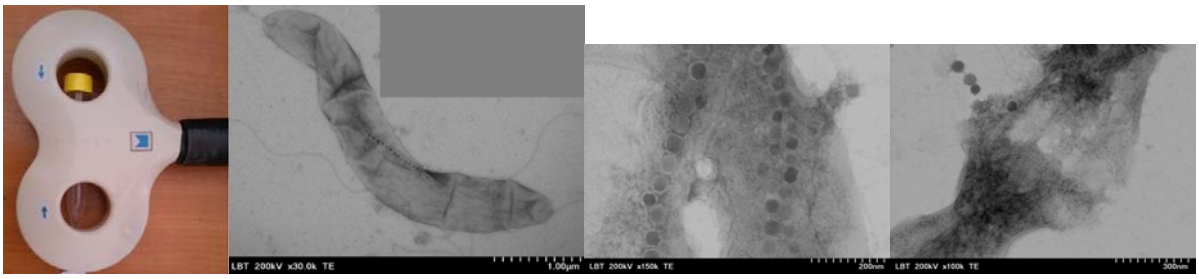
Magnetospirillum gryphiswaldense (DSM-6361) bacterial cells at stationary growth phase were suspended in culture medium at a concentration of 1.96×10^9 cell/ml (determined spectrophotometrically using a calibration curve of OD565 versus direct cell counts). Sample volumes of 2 ml were prepared for different PMFs exposure. Bacterial cells contain naturally-formed inner chains of magnetosomes (magnetite nanoparticles enveloped in a biological membrane, with an average diameter ≈ 40 nm) with lengths ranging between 0.6 – 1.2 μm. PMFs were generated by a Magstim Rapid 2 equipment enabled with a D70 Alpha coil model („figure of eight" shape coil, Fig. 1a). Average inductance of the coil was 16μH, coil diameter was 2 x Ø90 mm and peak magnetic field may reach 0.92 T. Three types of magnetic stimuli (S1...S3) were applied, at 100% power, in various pulses series, each pulse duration =400 μs : a) S1 (*burst stimulation*): total no. of pulses= 300, 10 bursts; b) S2 (*standard repetitive stimulation, no burst*) : total no. of pulses=100, 5 repetitions, cycle time=2 s, time between

* Miclaus Simona, simo.miclaus@gmail.com

repetitions =2.7 s; c) S3 (*single pulse*): total no. of pulses=10, repetition frequency=0.5 Hz. The spectral analysis of the magnetic field components (in air) was made by a Picoscope 3000 and by a Universal Software Radio Peripheral (USRP) platform connected to a magnetic field probe PBS_H4 from Aaronia A.G. Scanning-transmission electron microscopy of all exposed samples and of controls was applied, with the aim of observing structural changes / mechanic damage of cells due to magnetite nanoparticles displacement.

3. RESULTS AND DISCUSSION

The overall observations of micrographs indicated a clear affecting of the cellular integrity, especially after stimulus S1 (Fig. 1b), where the magnetosomes were leaked outside the cell. Otherwise, after all three stimuli types, the samples showed many destroyed cells, if compared against the control sample. In the case of intact cells in the all three samples, the number and, especially, the linear distribution of the magnetosomes were different than in the control sample. A statistical study has not yet been done to date, but planned. Also, identification of a damaging threshold, in connection to pulses parameters, is underway.



a b c d

Fig.1. a. The coil applicator used for magnetic pulses delivery and sample container beneath. b. Integer bacterial cell with inner chain of magnetosomes; c & d. Destroyed bacteria cells with magnetite nanoparticles leakage.

The mechanism of damage is unclear at the moment, but we hypothesize that it could be connected to both a type of electric poration and a type of magnetic rotation initiated along whole magnetite nanoparticles chains. Due to the significant heating of the coil during pulses delivery and possible heat transmission to the sample, we cannot exclude a superimposed thermal effect.

4. CONCLUSIONS

Pulsed magnetic fields at specific parameters, provided by TMS applicators, may initiate the damage of the cellular integrity in case of magnetite nanoparticle chains contained in bacterial cells.

REFERENCES

[1] Odutola, T., Myrovali, E., Makridis, A., Maniotis, N., Angelakeris, M., Kimiskidis, V., Samaras, T., Can magnetic nanoparticles thermally assist the beneficiary role of transcranial magnetic stimulation?, Proceedings of 1st World Conference on Biomedical Applications of Electromagnetic Fields (EMF-Med), Split, Croatia, Sept. 2018.

[2] Chen, R., Romero, G., Christiansen, M.G., Mohr A., Anikeeva, P., Wireless magnetothermal deep brain stimulation, Science, vol. 347, no. 6229, 2015, p. 1477-1480.

[3] Shankayi, Z., Firoozabadi, S.M., Mansourian, M., Mahna, A., The effects of pulsed magnetic field exposure on the permeability of leukemia cancer cells, Electromagnetic in Biology and Medicine, vol. 33, no. 2, 2014, p. 154-158.

[4] Meng, Y., Cellular level studies and coil system design for transcranial magnetic stimulation, Graduate Theses and Dissertations. 14511., Iowa State University Capstones, USA, https://lib.dr.iastate.edu/etd/14511, 2015.

[5] Soldati, M., Mikkonen, M., Laakso, I., Murakami, T., Ugawa, Y., Hirata, A., A multi-scale computational approach based on TMS experiments for the assessment of electro-stimulation thresholds of the brain at intermediate frequencies, Physics in Medicine and Biology, vol. 63, no. 22, 2018, paper no. 225006.