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Effects of Radio-Frequency Fields on Iron Cage Proteins: Dynamics and Iron Chemistry

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Extended Abstract

Biological components are commonly formed from diamagnetic or paramagnetic elements, and their interaction with magnetic fields is usually negligible. The result of non-ionizing radio frequency (RF) radiation in biology is therefore described in terms of the effect of an alternating electric field in a conducting medium and heating. However, iron is an essential element to most living organisms. For example, an adult needs between 10 and 18 mg of iron per day, the highest concentration of any metallic element. This is because of its crucial role in biochemical mechanisms such as oxygen transport and redox processes.

A key constituent in the chemical control of iron is the iron cage protein ferritin. Its role is to oxidize and store iron ions in the form of an oxide-hydroxide ferrihydrite nanoparticle –and then release the iron when it is needed via a chemical signal. Inside the peptidic cage, we can find a core nanoparticle as far as 8 nm in size with up to 4500 iron ions. This high iron content leads to a relatively high magnetic moment and superparamagnetic or single domain properties. Superparamagnetic nanoparticles can interact with electromagnetic irradiation in the RF range via Néel absorption/relaxation. This energy is irradiated to the surrounding proteic cage, which could lead to changes in its function of iron storage and delivery.

Via in-vitro titration measurements of iron absorption and release, we have strong evidence for a RF magnetic field effect in the iron cage protein function, even after the magnetic field is removed. In agreement with our hypothesis of an effect due to the inner superparamagnetic nanoparticle, the effect remains the same if the frequency-field product ($\omega \cdot H$) is constant, as long as the frequency of the field is well below the Néel frequency (which in our model horse spleen ferritin means below some 10 GHz). This is verified over a frequency range of 50 kHz – 5 MHz.

Our measurements show that, on average, the amount of iron released by proteins exposed to fields of 190 Ts^{-1} is a 40% smaller than for control samples. The effect has statistical significance at all the measured frequencies (200 kHz-2MHz) and down to fields of just 15 μT at 500 kHz. The effect remains the same independently of the conductivity of the solution, but depends strongly on the protein concentration, and disappears with the reducing agent 6-Hydroxydopamine.

For iron uptake, calculated after adding Mohr's salt to the ferritin solution, the rates in the hour following the exposure are on average a 20% slower for proteins exposed to 190 Ts^{-1} fields. As it happened with the iron release, the effect depends on the frequency-amplitude product. If the frequency of the magnetic field is set constant, the effect increases with the magnetic field amplitude, and only at the highest field (some 60 μT at 500 kHz) is the effect statistically significant with $p < 0.05$.

In conclusion, alternating RF magnetic fields may alter the molecular function of iron cage proteins. These alterations result on iron release rates reduced by almost half and iron intake rates reduced by 20% at high ferritin concentrations. We tentatively attribute the origin of these effects to changes in the symmetry pores.

References

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