Vitamin C, Ascorbic Acid, and Magnetic Fields

https://www.researchgate.net/publication/303016925_Effect_of_Magnetic_Field_on_Ascorbic_Acid_Oxidase_Activity_I
Effect of Magnetic Field on Ascorbic Acid Oxidase Activity 1985
A homogeneous magnetic field of 1.1 T strength exhibits a significant influence on the activity of the enzyme ascorbic acid oxidase in vitro. A Lineweaver-Burk plot of the reaction shows the typical pattern of a mixed-type inhibition, i.e. a larger rate of reaction at low substrate concentrations and a smaller rate of reaction at high substrate concentration than that of the control without magnetic field applied.
5.7 nmol of ascorbic acid and 1 unit of enzyme was mixed in 1 ml phosphate buffer and incubated for exactly 5 minutes inside and outside the magnetic field as described above.

https://pubmed.ncbi.nlm.nih.gov/22131325/
Extremely low frequency magnetic field induces oxidative stress in mouse cerebellum 2011
We have investigated whether extremely low frequency magnetic field (ELF-MF) induces lipid peroxidation and reactive oxygen species in mouse cerebellum. After exposure to 60 Hz ELF-MF at 2.3 mT intensity for 3 hours, there was a significant increase in malondialdehyde level and hydroxyl radical.
While glutathione contents were not altered, ascorbic acid levels were significantly decreased by ELF-MF exposure. These results indicate that ELF-MF may induce oxidative stress in mouse cerebellum.

https://www.nature.com/articles/s41467-020-17380-5
Magnetic field boosted ferroptosis-like cell death and responsive MRI using hybrid vesicles for cancer immunotherapy 2020
We report a strategy to boost Fenton reaction triggered by an exogenous circularly polarized magnetic field (MF) to enhance ferroptosis-like cell-death mediated immune response, as well as endow a responsive MRI capability by using a hybrid core-shell vesicles (HCSVs). HCSVs are prepared by **loading ascorbic acid (AA)** in the core and poly(lactic-co-glycolic acid) shell incorporating iron oxide nanocubes (IONCs). MF triggers the release of AA, resulting in the increase of ferrous ions through the redox reaction between AA and IONCs.
Iron-based nanomaterials such as superparamagnetic iron oxide nanoparticles[19], iron nanometallic glasses[20], iron cross-linked gel nanoparticles[21], and the iron-based metal−organic frameworks[22] have been extensively tested as ferroptosis-inducing agents recently. Their capability of ROS generation through Fenton reaction of ferrous (Fe^{2+}) or ferric (Fe^{3+}) ions is believed to play a critical role in achieving a sufficient cancer therapeutic effect.
Ascorbic acid (AA, $C_6H_8O_6$) can act as an electron-donor reducing ferric ions to ferrous state and finally forms dehydroascorbic acid[24,25]. As shown in Fig. 1c, Supplementary Figs. 3, 4, after 10-min MF treatment, the increase of ferrous ions was found in 0.1 h. The concentration of ferrous ions continued to increase when we prolonged the incubation time. In contrast, the HCSVs **without** MF treatment showed no changes of ferrous ion concentration in the same 6 h incubation period.
The generated ferrous ions, inducing stronger Fenton-like oxidation than ferric ions, triggered the higher accumulation of ROS, and finally inhibited tumor cell growth (Fig. 1d and Supplementary Fig. 9).
As shown in Supplementary Fig. 10, HCSVs and MF treated groups demonstrated significant ROS accumulation in the cells.
Based on the results, we concluded that ferroptosis was mainly induced by the combination of MF and HCSVs.
It is noteworthy to mention that the boosted ferroptosis and CRT accumulation followed by HCSVs and MF treatment will be promising for combinational immune cancer therapy applications.

https://link.springer.com/article/10.1007/s13197-020-04801-y
Impact of pulsed magnetic field treatment on enzymatic inactivation and quality of cloudy apple juice 2020
No significant effect on soluble solids was found under all processing parameters, whereas significant decreases of ascorbic acid were observed at the intensity of 7 T with 5–30 pulses.

https://pubmed.ncbi.nlm.nih.gov/22253132/
Effect of stationary magnetic field strengths of 150 and 200 mT on reactive oxygen species production in soybean 2012
In this study, soybean seeds treated with static magnetic fields of 150 and 200 mT for 1 h were evaluated for reactive oxygen species (ROS) and activity of antioxidant enzymes.
Magnetic field treatment resulted in enhanced production of ROS mediated by cell wall peroxidase while ascorbic acid content, superoxide dismutase and ascorbate peroxidase activity decreased in the hypocotyl of germinating seeds.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7691729/
Preparation of magnetic nanoparticle integrated nanostructured lipid carriers for controlled delivery of ascorbyl palmitate 2020
Magnetic hyperthermia (MH) is based on induction heating of MNps under application of an alternating magnetic field and the temperature increase in body tissues leading to cellular structure change. In high temperature, such as 40–43 °C, cancerous cells would be damaged but healthy cells survive. Basically, MH is focused on the destruction of tumors by heat, which is obtained from magnetic nanoparticles under the application of an alternating magnetic field (AMF) [17], [18], [19]. In addition to the use of MNPs individually, their integration into a drug-loaded nanocarrier and the application of local HP allows a combined therapy with a dual effect, while causing damage to the tumor cells locally and promoting the diffusion of the drug through the carrier. In this context, the modification of AA, as an antitumor agent, with PA and the administration of AP with MH by loading into MNp integrated NLCs (MNLCs), both providing locally high dosage AA application and local damaging of tumor cells can be considered as a promising and advantageous method that can be used in combined therapy.
When we look at the drug release% values in Fig. 13.A, it is seen that there is not much difference between free AA and AA-NLC in terms of percentage release. Looking at the released value after 1 h, it is seen that free AA is only 11% more than AA-NLC. This is the main reason why AA is chemically modified with palmitic PA and converted to AP. When looking at AP release from AP-NLC, it is observed that the release is slowed down considerably and converted into a controlled manner. While AA-NLC release% value was 83% after 1 h, this value was calculated as 23% for AP-NLC.

https://pubs.aip.org/aip/jcp/article/145/8/085101/561871/Sub-millitesla-magnetic-field-effects-on-the
Sub-millitesla magnetic field effects on the recombination reaction of flavin and ascorbic acid radicals 2016
Even though the interaction of a <1 mT magnetic field with an electron spin is less than a millionth of the thermal energy at room temperature (k_BT), it still can have a profound effect on the quantum yields of radical pair reactions. We present a study of the effects of sub-millitesla magnetic fields on the photoreaction of flavin mononucleotide with ascorbic acid. Direct control of the reaction pathway is achieved by varying the rate of electron transfer from ascorbic acid to the photo-excited flavin.
The effects of applied magnetic fields on photochemical reactions that have free radicals as intermediates can be explained by the radical pair mechanism.[1,2]

Ascorbic acid was recently suggested as a possible radical pair partner for the FAD radical in a cryptochrome magnetoreceptor.[15]

https://pubmed.ncbi.nlm.nih.gov/24671932/
Alternative radical pairs for cryptochrome-based magnetoreception 2014
We end with a very tentative and speculative suggestion for the identity of the putative Z† radical. Ascorbic acid (figure 5), a common biological reductant, can reduce photo-excited flavins [53] and Trp radicals [54] by hydrogen atom or electron transfer to form a radical in which there is one small (approx. 200 uT) and several very small (10-20 uT) hyperfine interactions [52,55].

https://scialert.net/fulltext/?doi=jas.2007.1279.1285
Protective Effect of Ascorbic Acid on Molecular Behavior Changes of Hemoglobin Induced by Magnetic Field Induced by Magnetic Field 2007
The results indicated that exposure of animals to magnetic field resulted in changes in the molecular behavior of hemoglobin molecule while treatment with ascorbic acid afforded comparatively more significant amelioration in these molecular changes, via decreasing the radical pair interaction of magnetic field with biological molecules.

https://www.researchgate.net/publication/40728270_Static_Magnetic_Field_Effect_on_the_Fremy's_Salt-Ascorbic_Acid_Chemical_Reaction_Studied_by_Continuous-Wave_Electron_Paramagnetic_Resonance
Static Magnetic Field Effect on the Fremy's Salt-Ascorbic Acid Chemical Reaction Studied by Continuous-Wave Electron Paramagnetic Resonance 2009
Static magnetic field effect in the framework of the radial pair mechanism (RPM) theory was studied on the biologically significant chemical reaction between ascorbic acid and Fremy's salt. The data indicate that the reaction rate depends on the applied magnetic field strength.

https://isom.ca/wp-content/uploads/2020/01/JOM_2001_16_3_10_The_Effect_of_Alternating_Magnetic_Field_Exposure_and-.pdf
The Effect of Alternating Magnetic Field Exposure and Vitamin C on Cancer Cells 2001
The authors have previously shown the potential therapeutic effect of very high-dose intravenous vitamin C (ascorbic acid, ascorbate, AA) in the treatment of cancer.1-6 We showed 50 percent inhibition of tumor cells with vitamin C concentration at 200 mg/dL in dense monolayer cell culture and 400 mg/dL for the hollow fiber culture model.1 Since it is **difficult to to maintain this high level of vitamin C in blood for long periods of time**, we were interested to see if cytotoxicity of cancer cells could be obtained by using lower concentrations of vitamin C in combination with alternating magnetic fields. Low frequency pulsed magnetic fields (LFMF) and rotating magnetic fields (RMF) were used.
The purpose of our study was to examine the anti-tumor effect of vitamin C combined with magnetic field treatments. The inhibitory effect of vitamin C in cancer cells involves its interaction with several compounds: glutathione (GSH), hydrogen peroxide and the enzyme catalase. 17,18 In the blood, vitamin C is oxidized to dehydroascorbate (DHA). DHA is easily transported across cell membranes where it is then reduced by GSH back to vitamin C. Cancer cells have a high level of GSH compared to normal cells. The higher level of GSH for the same level of vitamin C produces more hydrogen peroxide. In normal cells, catalase inactivates hydrogen peroxide by converting it to water and oxygen. Cancer cells have a reduced (10 to 100 fold) intracellular level of catalase. This results in very high levels of hydrogen peroxide and oxidative by-products in the cancer cell. 18 Hydrogen peroxide is toxic and destroys the cancer cells.
The control group was vitamin C alone, the treatment group was vitamin C combined with LFMF. Both were exposed two hours per day.
Data from four different experiments are shown. The LFMF induced cell death at a much lower level than just vitamin C alone.
There was 80 percent cell death (20 percent survival) at 120 mg/dL of vitamin C and LFMF while the vitamin C group needed 220 mg/dl for the same response.
Figure 3 (p.3) shows the effect of the rotating magnetic field (RMF, 40 gauss, 1000 rpm) on human pancreatic cancer cell lines (MiaPaCA). The control group received treatment with vitamin C only. An 80 percent cell death (20 percent survival) was achieved with 160 mg/dL of vitamin C in the magnetic field treatment group. It required 360 mg/dL to achieve the same effect with vitamin C only treatment group.

Figure 2. Response of human fibrosarcoma to LFMF + vitamin C and vitamin C only

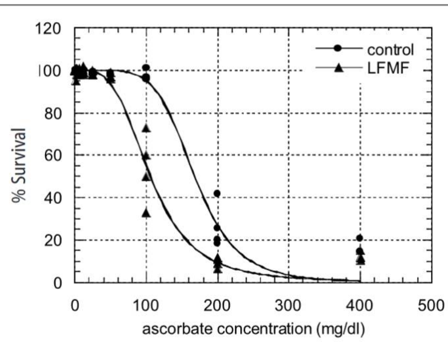

Figure 3. Effect of rotating magnetic field (RMF) on human pancreatic cancer cells (MiaPaCa).

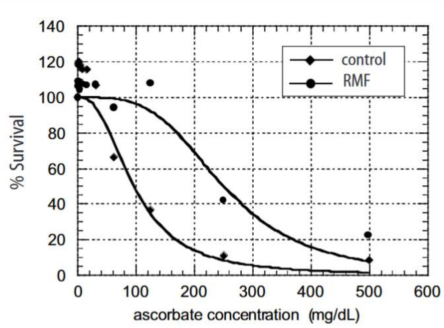

Figure 4 (below) shows the effect of combined treatment by LFMF plus ascorbate or ascorbate alone on survival of human colon carcinoma cells SW620 grown inside the hollow fiber as a three-dimensional tumor cell structure. To investigate the possibility that vitamin C or LFMF could induce cell growth, tumor cell lines and normal fibroblasts were exposed to 30-100 Hz for three to four hours over a three day period. There was no increase in the growth rate of tumor cells or normal cells. It appears from our data that vitamin C combined with low frequency magnetic field or rotating magnetic field reduces the amount of vitamin C to induce 50 percent inhibition of tumor cells. This widens the therapeutic window of vitamin C and does not harm normal cells.

Figure 4. Response of human colon carcinoma cells SW620 grown as hollow-fiber in vitro solid tumor model to LFMF + vitamin C and vitamin C only.