Can Strong Magnetic Fields Influence the Growth of Cancer Cells?

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The recent development of extremely high magnetic fields by superconducting coils, which create fields up to 300 kilogauss, raises the question of whether biological tissue and especially the more vulnerable tissue of cancer cells can be influenced by exposure to these ultrastrong magnetic fields.

Any physical method designed to act on a tumor must have two requirements: 1) It has to penetrate deeply the tissue and 2) shall attack only the cancer cells.

The first requirement can be satisfied by any deeply penetrating field. Until now only those methods based upon radiation fields of X-rays and temperature fields have been employed with partial success. Both methods apparently do not comply with the second requirement. Only the fact that tumor cells are more vulnerable than normal cells explains why these methods have any success at all.

The now available ultrastrong magnetic fields seem to offer a third method in which the second requirement may be achieved.

In this note we will show that this method must be taken seriously. A magnetic field exerts forces on a paramagnetic or diamagnetic substance. Cellular material consists of proteins and nucleic acids submerged in protoplasm consisting mainly of water and with a magnetic susceptibility relative to water of approximately $\chi = 1.3 \times 10^{-5}$. For the magnetic field to exert a force on the substance it must be inhomogeneous. The force on a body with a susceptibility $\chi$ can be calculated from the "magnetic pressure" on the material given by

$$p = \chi \frac{H^2}{2}.$$  \hfill (1)

In equation (1) $H$ is the magnetic field strength. A net force results from the difference in the magnetic pressure on opposite sides of the body. For a body of thickness $\delta$ we obtain from (1) for this difference in pressure

$$\Delta p = \chi \frac{(H-V)H}{3 \delta}. \hfill (2)$$

Take for instance $\chi = 1.3 \times 10^{-5}$, $H = 2 \times 10^4$ gauss, $|\nabla H| = 5 \times 10^4$ gauss/cm, and $\delta = 10^{-4}$ cm (typical diameter for a cell). It follows that $\Delta p \approx 13$ dyn/cm$^2$.

The tensile strength $\sigma$ of cellular membranes is of the order $\sigma \approx 1$ dyn/cm$^2$. The magnetic field may therefore tear the membrane of a cell apart.

In a dividing cell, such as a cancer cell, the membrane of the nucleus is dissolved and rebuilt. It seems therefore, to be possible to sustain the magnetic field at a value high enough to prevent the membrane of the nucleus in a dividing cancer cell from being rebuilt, however, at a value low enough as not to damage the membranes of normal cells.

To look at the action of the magnetic field in a different way, we observe that the force on a magnetized spherical body of a radius $r$ in an inhomogeneous magnetic field is given by

$$F = (M \cdot \nabla) H, \hfill (3)$$

where the induced magnetic moment $M$ is

$$M = \frac{(4 \pi)^3}{3} \chi r^3 H. \hfill (4)$$

Consider an intracellular particle with a radius $r = 10^{-5}$ cm and assume for $\chi$, $H$ and $|\nabla H|$ the same values as before. From (3) and (4) it follows $F \approx 6.5 \times 10^{-7}$ dyn. Assuming for the particle a density $\rho \approx 1$ g/cm$^3$ one computes the acceleration under this force to be $a = 1.6 \times 10^4$ cm/sec$^2 = 1600$ g. The physical effects on biological tissue under an accelerating force equivalent to 1600 g is certainly not negligible. In applying this result, it seems quite possible that chromosomes are affected in such a way as to disrupt the normal process of cellular division.

The predictions made on the basis of these estimates could be checked experimentally in a tissue culture exposed to a strong magnetic field. The magnetic field has to be generated with a super-conducting coil submerged in liquid Helium of a cryostat. The change in the cellular growth of the tissue culture can then be observed optically with a phase contrast microscope.

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