Genetic Effects of Nonionizing Electromagnetic Fields

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(1) Radiofreqency radiation (wireless communication signals)

(2) Extremely low frequency electromagnetic fields (ELF EMF)

(3) Cancer

Radiofreqency radiation
(wireless communication signals)

- **Gene expression (Czyc; Fritz; Goswami; Harvey & French; Ivaschuk; Morrisey; Pacini)**
- **Micronucleus formation (Bisht; d'Ambrosio; McNamee; Tice; Vijayalaxmi; Zeni)**
- **Chromosomal aberrations (Gadhia; Maes; Mashevich; Sykes; Vijayalaxmi)**
- **Sister chromatid exchange (Antonopoulos; Gadhia; Maes)**
- **DNA damage (Hook; Li; Malyapa; McNamee; Phillips)**
- **Gene mutation (Gos; Takahaski)**

Studies on Genetic effects of Wireless Communication-related Signals

Effect: Czyz (04); d'Ambrosio (02); Goswami (99); Gadhia (03); Harvey & French (00); Ivaschuk (97); Maes (96a,b); Mashevich (03); Pacini (02); Phillips (98); Sykes (01); Tice (02)

No Effect: Antonopoulos (97); Bisht (02); Fritz (97); Gos (00); Hook (04); Li (01); Maes (01); Malyapa (97); McNamee (02a,b, 03); Morrisey (99); Takahaski (02); Vijayalaxmi (01a,b, 03); Zeni (03)

Extremely low frequency electromagnetic fields

DNA strand breaks (Comet assay)

Studies reporting effect:

Ahuja: **50-Hz. 1 hr, 0.2-2 mT, human lymphocytes**

Ivancsits**- 50-Hz, intermittent, 1 mT, human fibroblasts**

Lai & Singh: **60-Hz, 2 hrs, 0.1-0.25 mT, rat brain cells**

Phillips: **60-Hz, 24 hrs, 0.1 mT, leukemia cells**

Svedenstal:**50-Hz ,32 days-7.5 μT, 14 days-0.5 mT, mouse brain cells**

Zmyslony: **50-Hz, 3 hrs, 7 mT, + iron, human lymphocytes**

Studies reporting no effect:

Fairbairn & O'Neill: **50-Hz, 5 mT, human lymphocytes**

McNamee: **60-Hz, 2 hrs, 1 mT, immature moue cerebellar cells**

Miyakoshi: **50-Hz, >50mT, human glioma; potentiated x-ray-induced DNA single strand breaks**

Reese: **60-Hz, 1 hr, 0.1-2 mT, Chinese hamster cells**

Stronati: **50-Hz, 2 hrs, 1 mT, human blood cells**

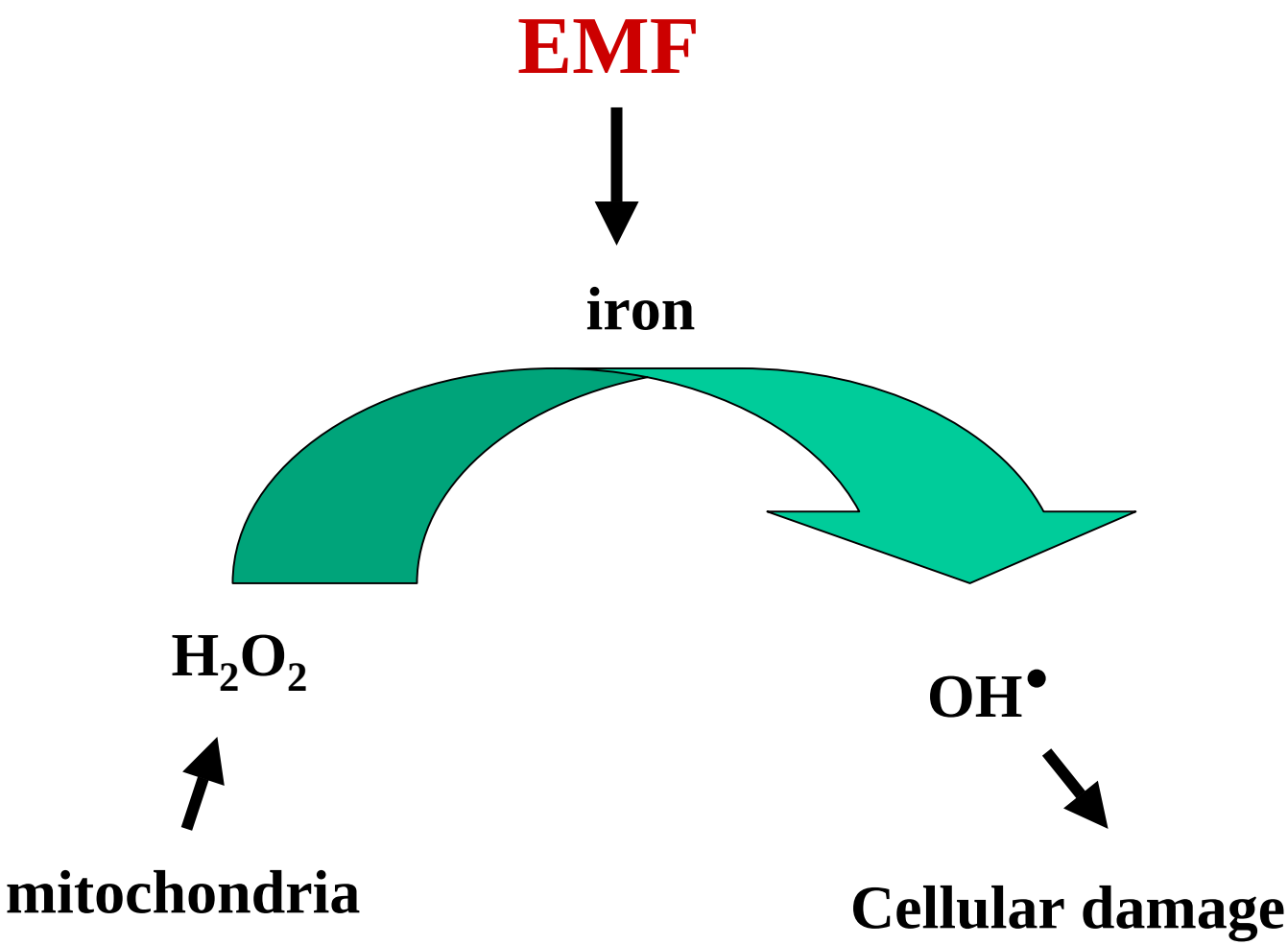
Magnetic Field and Free Radicals (Lai & Singh)

Magnetic field-induced DNA strand breaks can be blocked by melatonin, N-tert-butyl-α-phenylnitrone (a spin-trap compound), Trolox (a vitamin E analog), 7-nitroindazole (a nitric oxide synthase inhibitor), and the iron-chelator deferiprone.

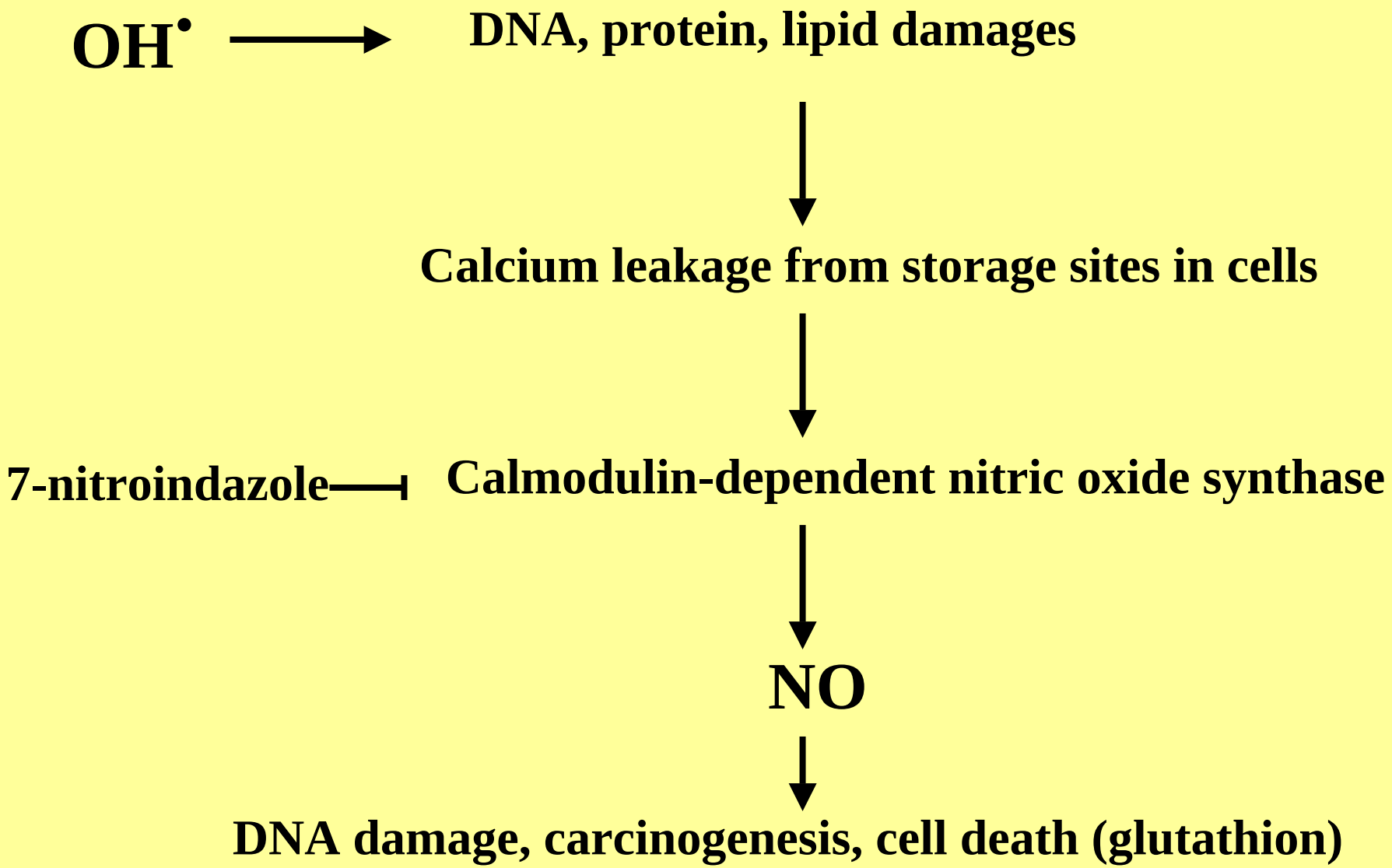
Zmyslony reported an increase in DNA strand breaks in lymphocytes exposed to a 50-Hz magnetic field in the presence of ferrous chloride in the medium, whereas exposing the cells in the absence of ferrous ion had no significant effect

Jajte showed that the effect was blocked by melatonin, suggesting the involvement of free radicals.

Lourencini de Silva reported that electromagnetic fields caused damage in DNA plasmids in the presence of a transition metal (Sn).



THE FENTON REACTION


OH•
DNA, protein, lipid damages
Calcium leakage from storage sites in cells
7-nitroindazole
Calmodulin-dependent nitric oxide synthase
NO
DNA damage, carcinogenesis, cell death (glutathion)

Two possible outcomes:

-exogenous and endogenous cellular antioxidation processes will keep the damages in check by neutralizing free radicals and eventually the cell will repair itself and survive. However, DNA damage and repair could lead to mutation and increase the chance of carcinogenesis.

-If the processes of free radical damage are not checked by cellular anti-oxidation and repair processes, the cell will die.

(1) Cells with high rates of iron intake, e.g., proliferating cells, cells infected by virus, would be more susceptible to the effects of magnetic fields.

(2) cells with high metabolic rates, such as brain cells, would be more susceptible to the effects of magnetic fields because hydrogen peroxide, the substrate of the Fenton reaction, is a metabolic product of mitochondria.

(3) The outcome of oxidative damage induced by magnetic fields depends on various factors, including the oxidative status of the cell, capability of endogenous antioxidation enzymes and processes to counteract free radical build up, availability of exogenous antioxidants, iron homeostasis (a balance of iron influx, storage, and usage).

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Radiofrequency radiation

Lai H, Singh NP. Melatonin and a spin-trap compound Blocked radiofrequency radiation-induced DNA strand Breaks in rat brain cells. *Bioelectromagnetics* 18: 446-454, 1997.

Zmyslony M, Politanski P, Rajkowska E, Szymczak W, Jajte J. Acute exposure to 930 MHz CW electromagnetic radiation in vitro affects reactive oxygen species level in rat lymphocytes treated by iron ions. *Bioelectromagnetics.* 25(5):324-328, 2004.

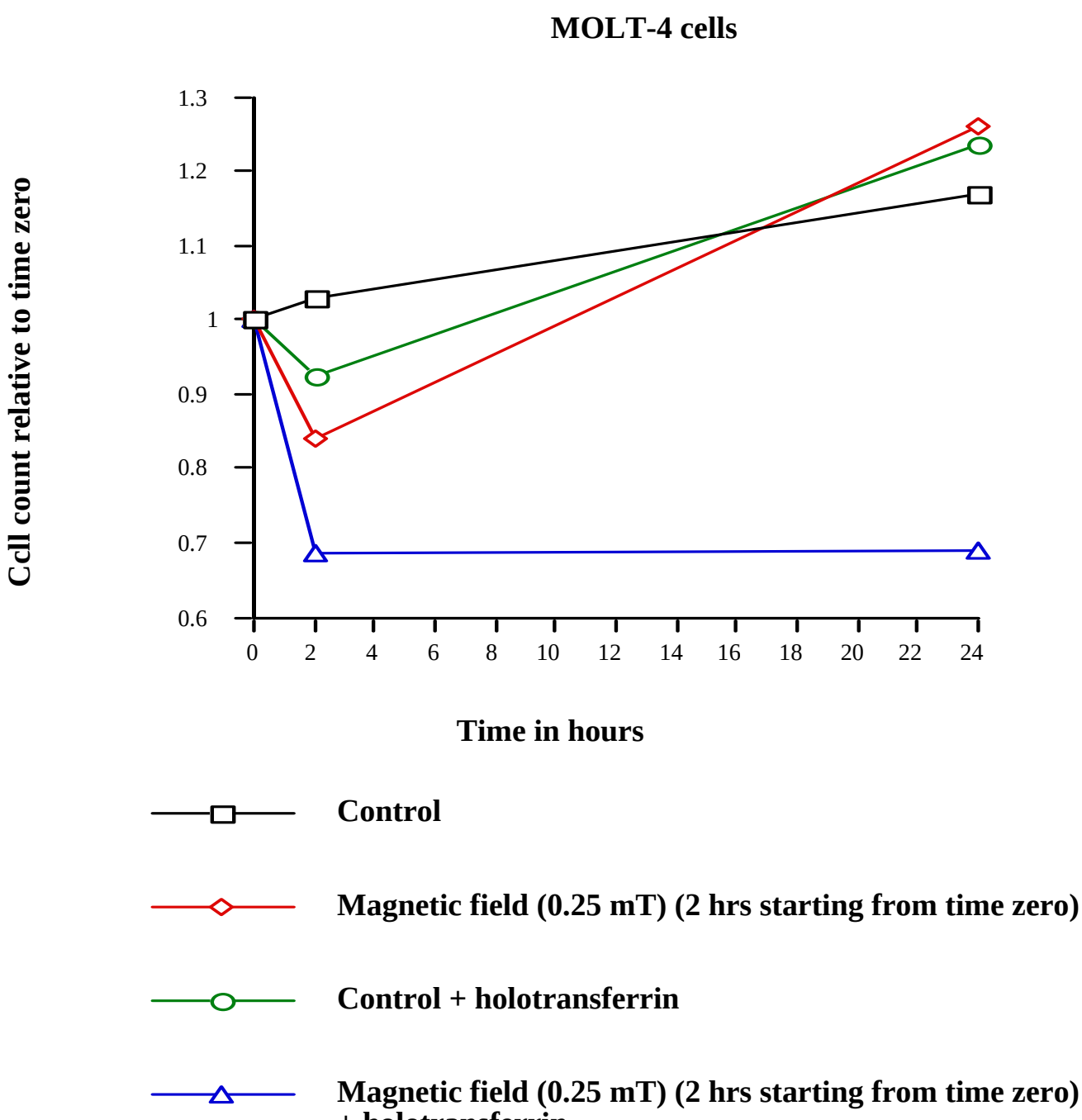
Cancer

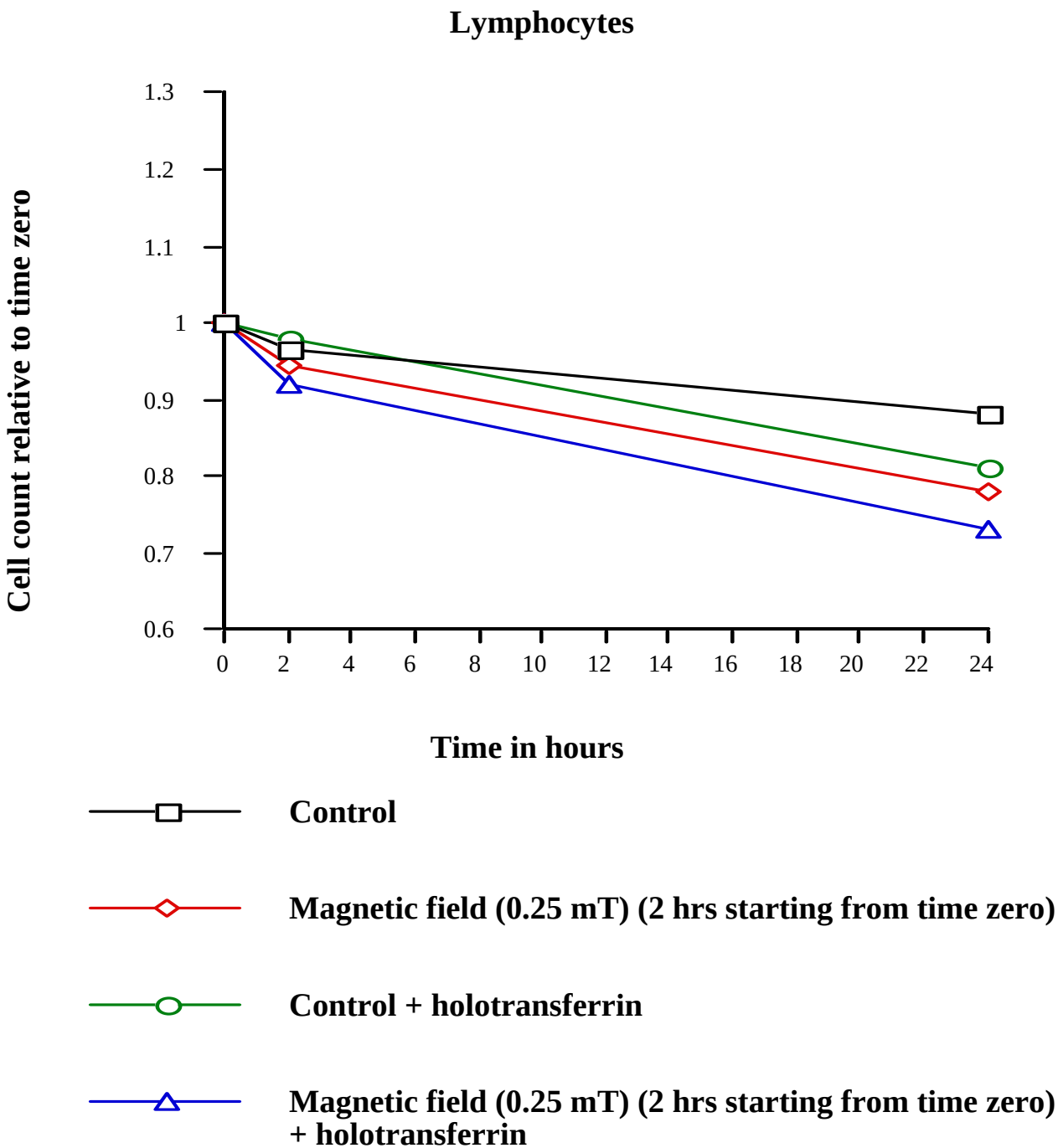
Cancer cells have high iron Content.

Do magnetic fields affect cancer cells?

-Possible involvement of iron and free radicals in effect of magnetic field on cancer cells

-Human leukemia cells (Molt-4)
-Provide cells with iron


MOLT-4 cells
Cell count relative to time zero
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0
2
4
6
8
10
12
14
16
18
20
22
24
Time in hours
Control
Magnetic field (0.25 mT) (2 hrs starting from time zero)
Control + holotransferrin
Magnetic field (0.25 mT) (2 hrs starting from time zero) + holotransferrin


Lymphocytes
Cell count relative to time zero
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0
2
4
6
8
10
12
14
16
18
20
22
24
Time in hours
Control
Magnetic field (0.25 mT) (2 hrs starting from time zero)
Control + holotransferrin
Magnetic field (0.25 mT) (2 hrs starting from time zero) + holotransferrin

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Epidermoid carcinoma in mice
Pulsed magnetic field
5 mT, 250 pulses per second
Cis-platin
1 hr on day 0, 7, and 14

Magnetic field: no effect alone, enhanced drug effect

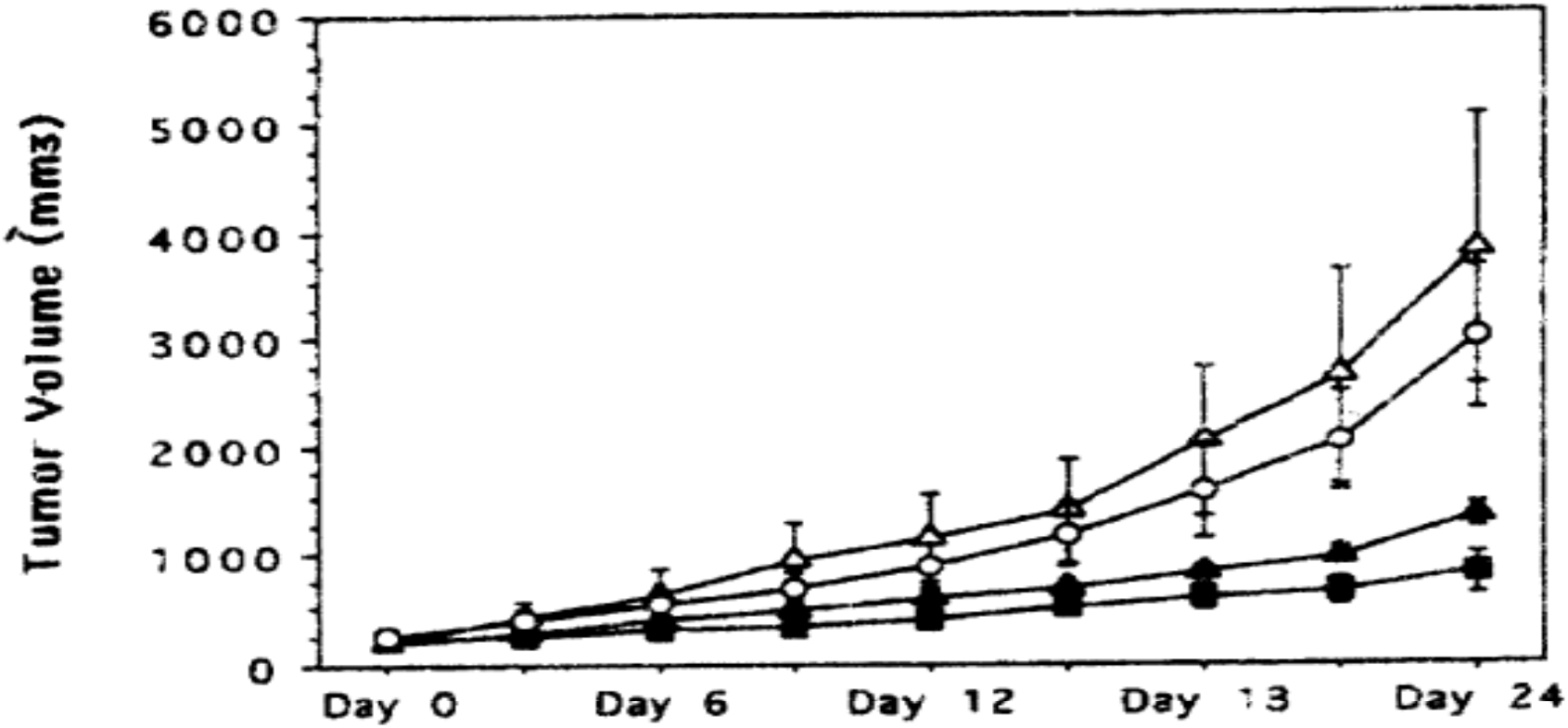

Figure 1. *Treatment of epidermoid carcinoma A-431 xenografts in nude mice with cisplatin and pulsed magnetic fields (PMF). Tumor measurements were taken every third day. Three treatment applications were made starting on experimental day 0 and again on days 7 and 14. Tumor volumes are mean values with 1 S.E. indicated by the error bars. (* —○—*, saline control group;* —△—*, Pulsed Magnetic Field group:* —▲—*, cisplatin alone group;* —■—*, PMF+cisplatin treatment group).*

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Colon carcinoma in mice
Pulsed magnetic field
5 mT, 250 pulses per second
Carboplatin
1 hr on day 0, 1, and 2

Magnetic field: no effect alone, enhanced drug effect

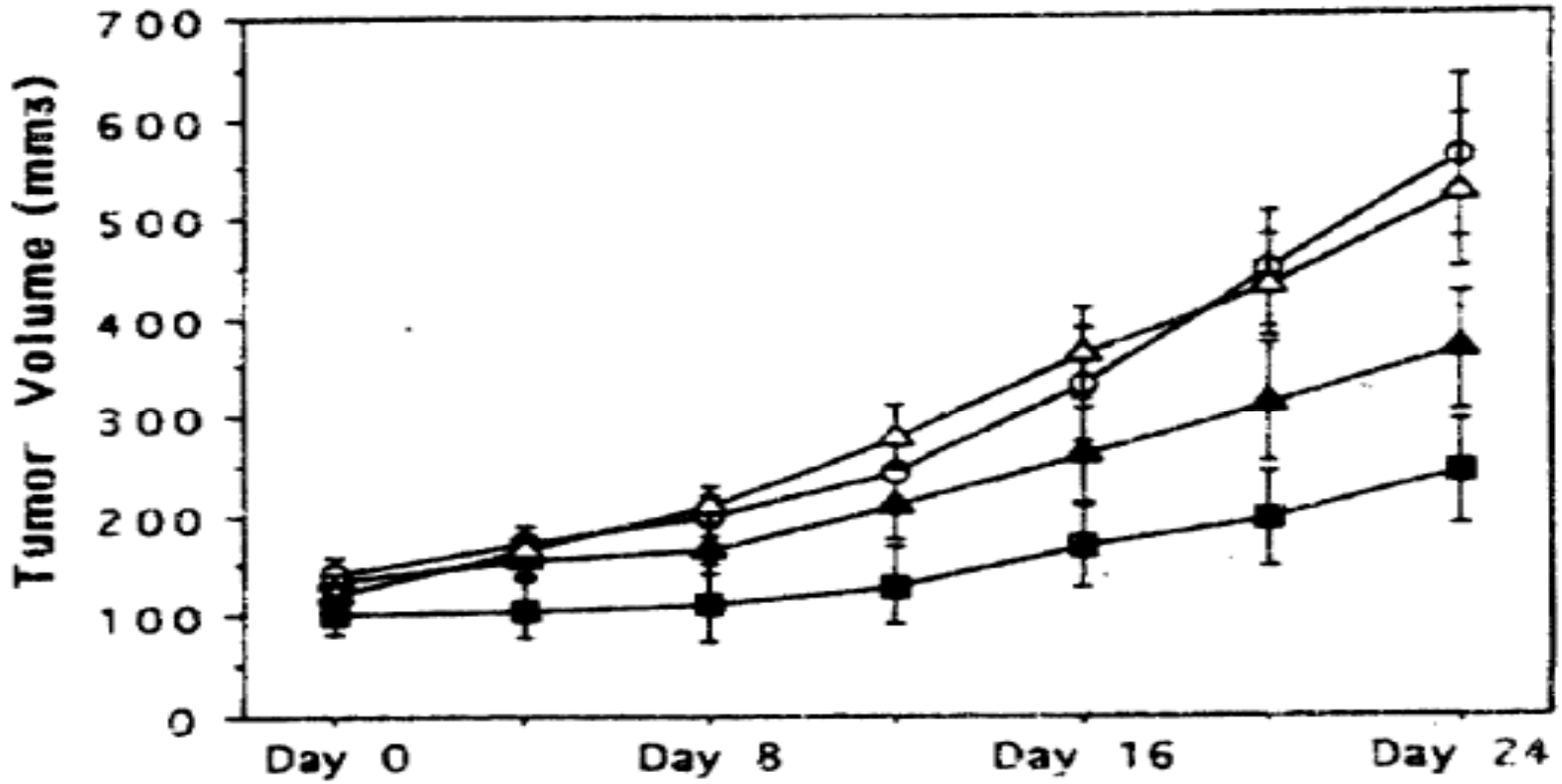

Figure 2. *Treatment of colon carcinoma HT-29 xenografts in nude mice with carboplatin and pulsed magnetic fields (PMF). Tumor measurements were taken every third day. Three treatment applications were made starting on experimental day 0 and again on days 2 and 3. Tumor volumes are mean values with 1 S.E. indicated by the error bars. (—○—, saline control group: —△—, Pulsed Magnetic Field group; —▲—, carboplatin alone group: —■—, PMF+carboplatin treatment group).*

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Colon carcinoma in mice
Pulsed magnetic field
5 mT, 250 pulses per second
Doxorubicin
1 hr on day 0 and 7

Magnetic field: retarded cancer growth; enhanced drug effect

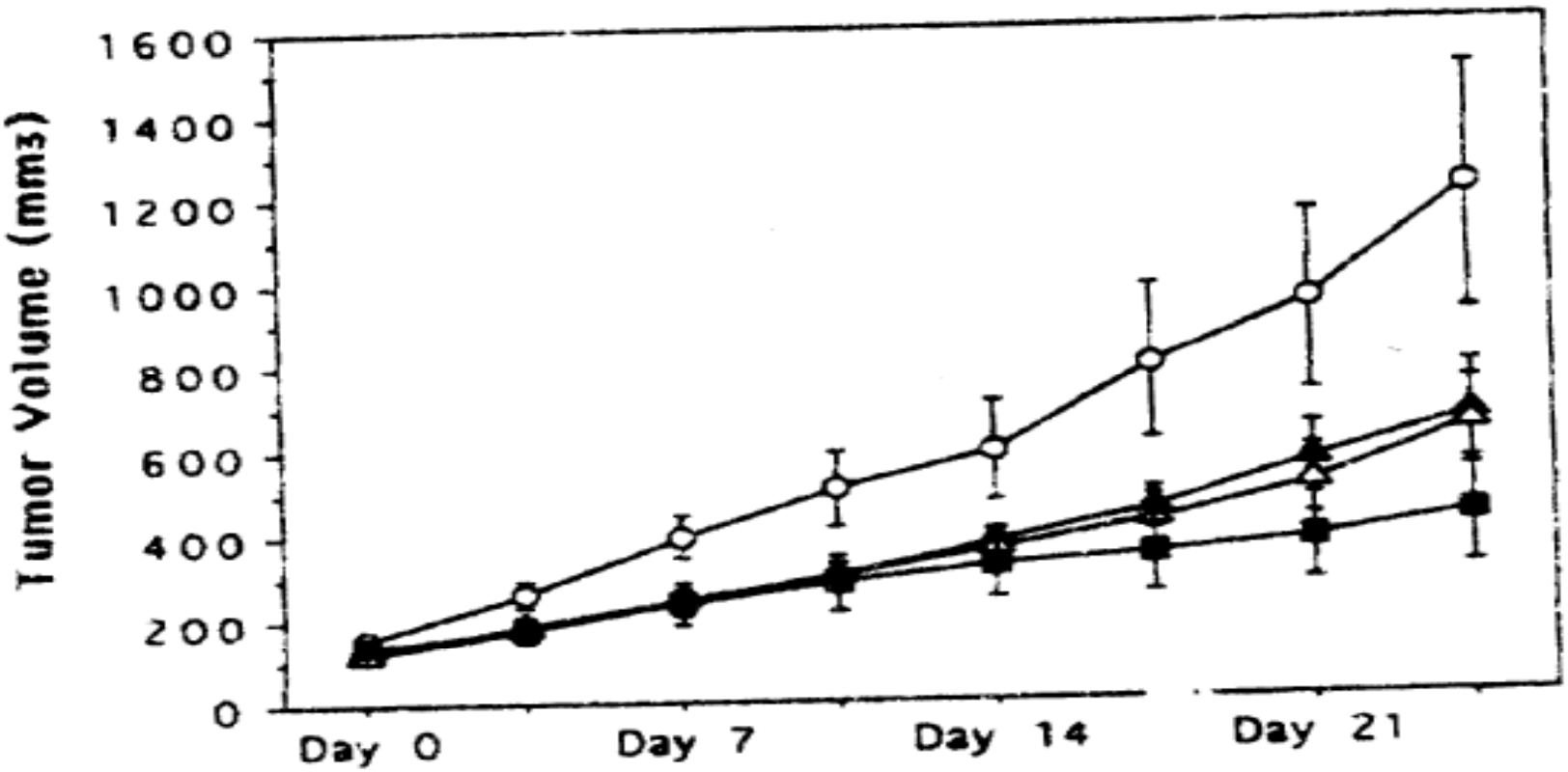
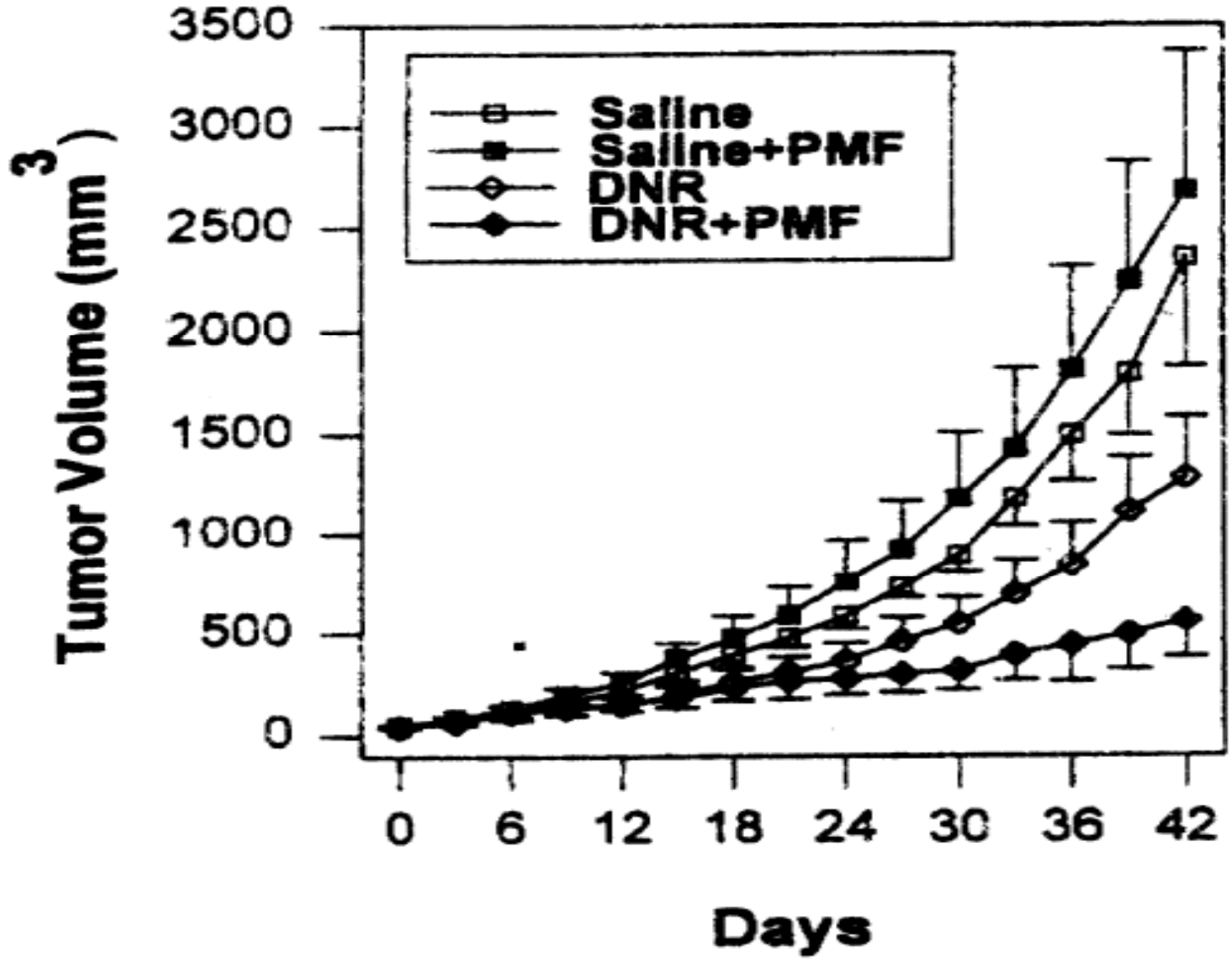


Figure 3. *Treatment of colon carcinoma HT-29 xenografts in nude mice with doxorubicin and pulsed magnetic fields (PMF). Tumor measurements were taken every third day. Two treatment applications were made starting on experimental day 0 and again on day 7. Tumor volumes are mean values with 1 S.E. indicated by the error bars. (—○—, saline control group; —△—, Pulsed Magnetic Field group; —▲—, doxorubicin alone group; —■—, PMF+doxorubicin treatment group).*

Hannan et al.

Multidrug resistant carcinoma in mice
Pulsed magnetic field
5 mT, 250 pulses per second
Daunorubicin
1 hr on day 0, 7 and 14

Magnetic field: no effect alone; enhanced drug effect


Tumor Volume (mm^3)
3500
3000
2500
2000
1500
1000
500
0
Saline
Saline+PMF
DNR
DNR+PMF
0
6
12
18
24
30
36
42
Days

De Seze et al.

Benzo(a)pyrene-induced tumor in mice
100 mT, square wave, 0.8 Hz
8 hrs/day, 5 days/week

Magnetic field: improved survival

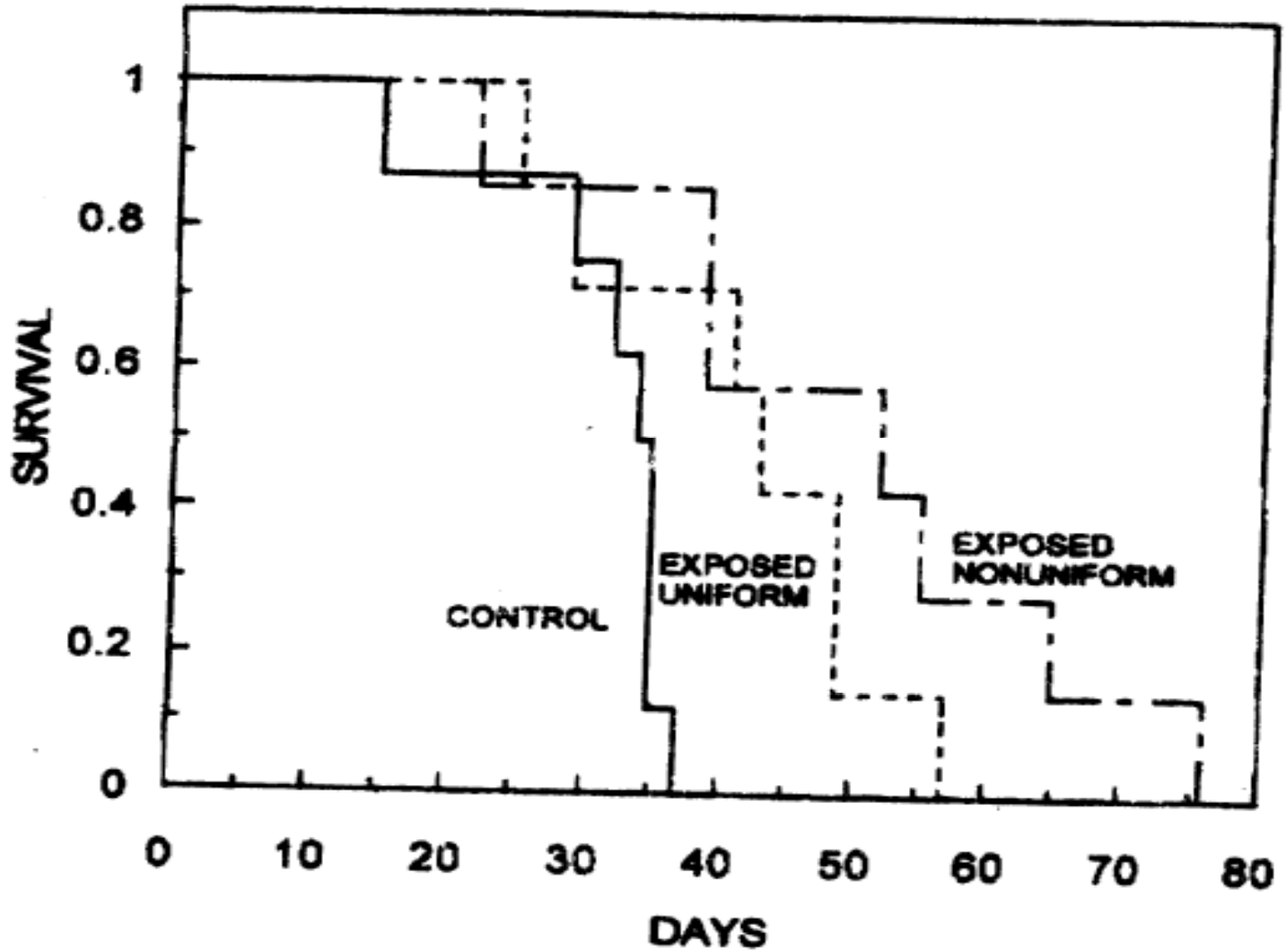


Fig. 3. Survival curves for C57/Bl/6 mice. Control mice (N = 8); mice exposed to the uniform field (N = 7); mice exposed to the non-uniform field (N = 7).

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Colon adenocarcinoma in mice
5.5 mT, 50 Hz
70 min per day

Magnetic field: improved survival

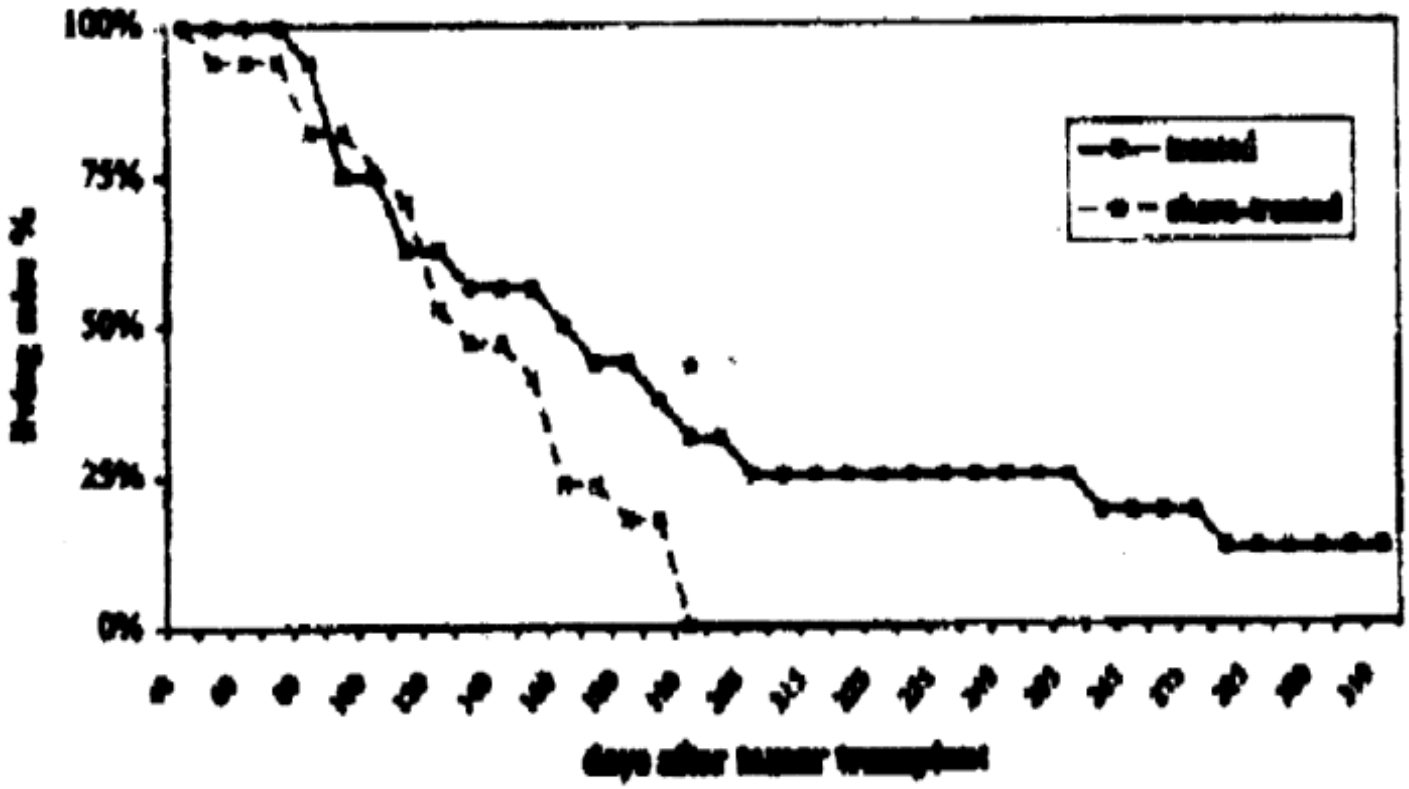

Fig. 2. Animal survival study. The curve reports the number of mice still alive on different days. Data refer to 16 treated and 17 sham-treated animals from day 1 to their natural death. ($^{*}P < 0.05$ on the basis of Mantell-Cox test).

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Lung carcinoma in mice
Cis-platin
~3 mT, 50 Hz
35 min per day, 7 days/week

Magnetic field: no effect alone; enhanced drug effect

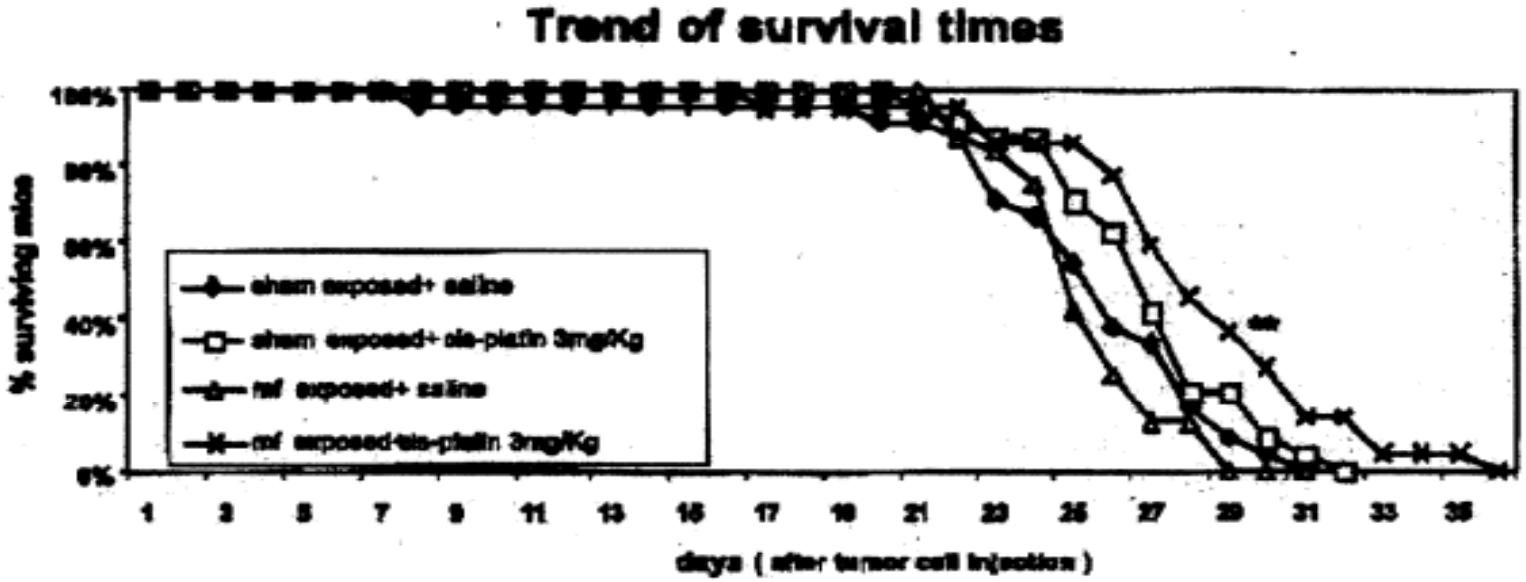

Fig. 3. *Cis*-platin pooled data from the first and second experiments. The curve reports the percentage of mice still alive on different days from i.m. injection of LLC cells. Data refer to 23 mice treated with *cis*-platin low dose (3 mg/kg i.p. on days 4, 8 and 12) and MF-exposed, 23 mice treated with *cis*-platin and sham-exposed, 23 mice MF-exposed and 23 mice sham-exposed. (** $P < 0.01$ on the basis of Mantel–Cox test).

Tofani et al.

Lung carcinoma in mice
Cyclophosphamide
~3 mT, 50 Hz
35 min per day, 7 days/week

Magnetic field: no effect alone;
Did not enhance drug effect

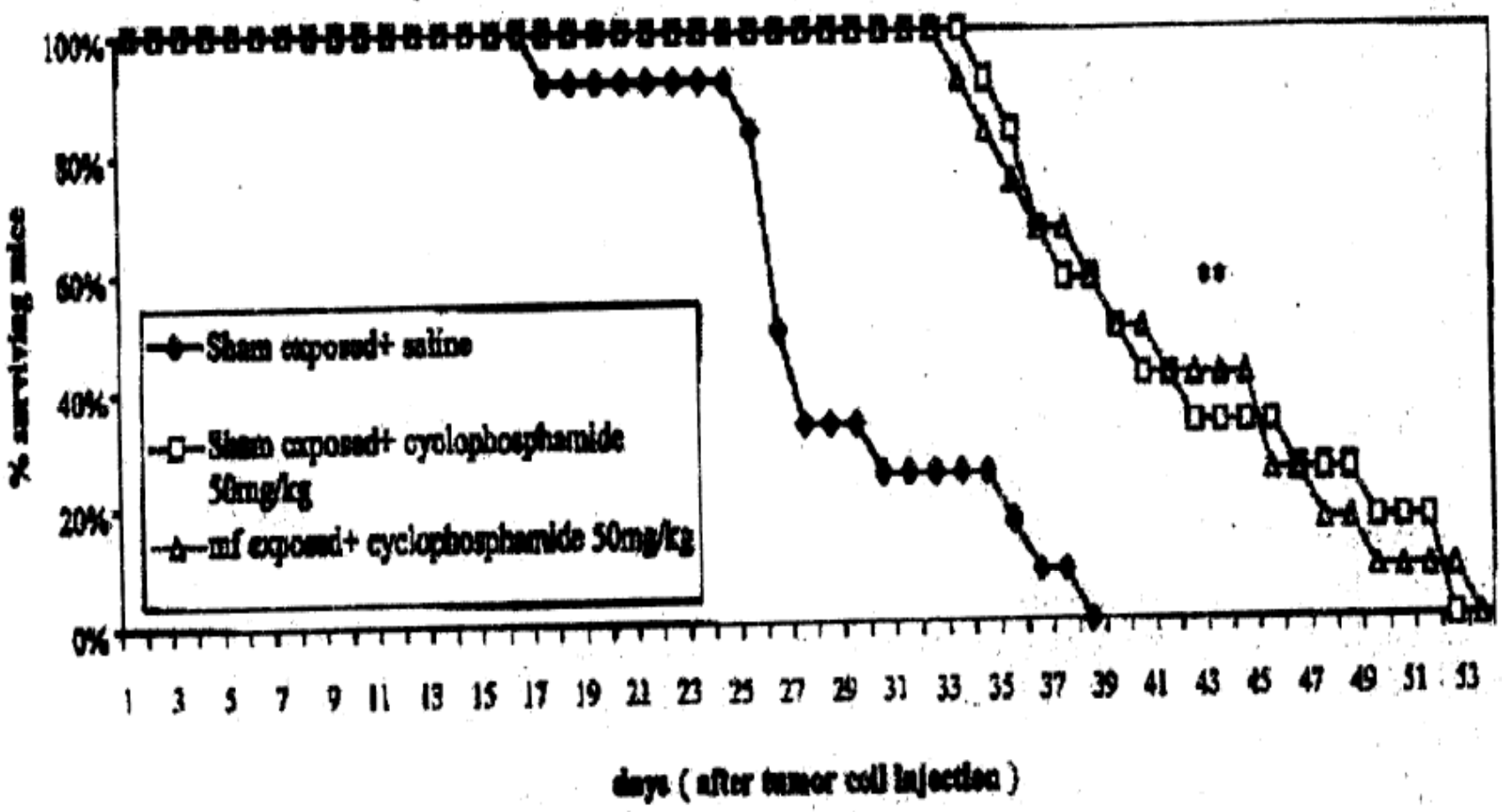

Fig. 5. Cyclophosphamide second experiment. The curve reports the percentage of mice still alive on different days from s.c. injection of B16 cells. Data refer to 12 mice treated with cyclophosphamide and MF-exposed, 12 mice treated with cyclophosphamide and sham-exposed (** $P < 0.0001$ on the basis of Mantel–Cox test) and 12 mice sham-exposed from day 1 to their natural death.

Magnetic field alone affects cancer growth.

Magnetic field enhances effects of some cancer chemotherapeutic drugs.


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