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Effect of static magnetic fields on survival of leukaemia-prone AKR mice

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Summary. The influence of a life-long exposure to static magnetic fields (SMF) on the lifespan of female AKR mice which develop spontaneous lymphoblastic leukaemia was investigated. Exposure all day long to a circular SMF, 4.6 mT maximal intensity or 2 h a day, 5 consecutive days a week to a uniform SMF of 400 mT did not modify the lifespan of mice. Exposure 2 h a day, 5 consecutive days a week to a uniform SMF of 600 or 800 mT modified the lifespan: about 50% of the population had a longer survival than the controls. Mice exposed 30 min a day 5 consecutive days a week to a non-uniform SMF presented the same trend.

Introduction

Modifications of the leucocyte population in vivo by exposure to static magnetic fields (SMF) have been reported by several authors. By exposing mice continuously in an almost uniform vertical SMF, a decrease in the leucocytes count has been observed [2, 3]. When the exposure was stopped at the minimum time period the number of leucocytes increased and ran over the normal population. Such a rebound following exposure to SMF has also been reported by Piruzian [13] for mice, Dernov [12] for mice and rabbits and Likhachev [10] for rabbits. By exposure to non-uniform SMF, J.M. Barnothy [1] reported the rejection of homogenic tumors transplanted in mice and a lengthening of lifespan in the case of syngenic grafts. Lenzi [9] noted less favourable results with Ehrlich adenocarcinoma grafts in mice when they were immediately exposed to SMF. Eiselen [7] with the same carcinologic model established no effect of a SMF. However the conditions of exposure were not exactly alike in these two experiments. By implanting magnetic disks in rats Kogan [8] observed a faster development of less differentiated chemically induced carcinoma.

In previous works we obtained no effect of a uniform SMF either on Lewis tumor graft [5] or on methylcholanthren carcinogenis [4] in mice.

In the present experiment we used AKR mice which develop spontaneous viral lymphoblastic leukaemia.

Material and methods

Eight-week old female AKR mice (IFFA-CREDO l'Arbresle, France) were used. Three experimental modes were followed during exposure. Fifty seven mice were exposed to a circular SMF created by a coil. This coil made of enameled copper 0.25 cm in diameter, formed a square section single turn 2.17 m average diameter, 6 × 8 cm section, 6 cm thickness. It was made up of 4 coils supplied in parallel with a 9.5 V voltage (Fig. 1 a). The total number of ampere-turns used was about 1720. The strength of the MF at the center was 1 mT. The coil was put between two sheets of aluminium, a glass plate was set on the upper sheet through rubber pieces. The mice were placed in plastic cages on the glass plate (Fig. 1 b). The maximal strength of MF at the level of the mice was 4.6 mT. The mice were divided into 3 groups of 15, and one group of 12. They stayed in the field all day long except for cleaning and weighing. Fifty seven mice were used as controls. They were put under the same conditions as the exposed ones without the MF.

To obtain a strong MF an LMM 300 electromagnet was used. The horizontal polar parts were 30 cm in diameter and delimited a pole gap 7 cm wide. The intensity of the current was regulated by a rheostat. The electric source and coils were water-cooled. When both of the polar parts were flat the SMF was uniform. The substitution of one flat polar part with a conic one creaded a non-uniform SMF. For exposure, an altuglas parallel-epipedic container measuring 68 × 114 × 298 mm was divided into two series of nine compartments 29 × 29 × 100 mm; each compartment could contain one mouse. The controls were placed into an identical container, between two metallic sheets, for the same length of time.

Fifty nine mice were exposed to an uniform SMF: 31 to 400 mT, 14 to 600 mT, 14 to 800 mT. The length of exposure was 2 h a day, 5 consecutive days a week. There were 44 control mice.

Twenty five mice were exposed to a non-uniform SMF. The maximum field strength was 900 mT with an average gradient of 30 $mT.cm^{-1}$. Twelve mice were exposed 30 min a day and 13 were exposed 2 h a day. Exposures continued for 5 consecutive days a week. Fourteen control mice were put into the container for 1 h a day.

All the mice were exposed from the age of 9 weeks until death. Then thymus and spleens of the dead mice were weighed.

Results

Exposure to the circular SMF

The lifespans are represented in Fig. 2, the averages of the weights of thymus and spleens are reported on Table 1. Exposure to the MF shows no difference.

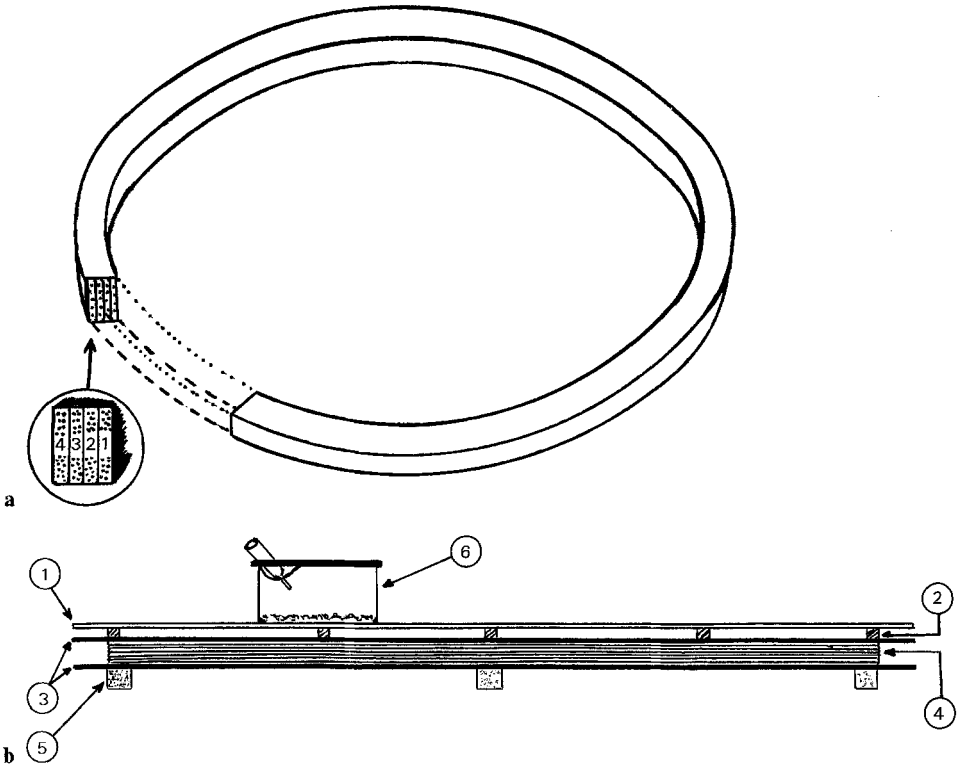

Fig. 1.a Sketch of the coil which creates a circular static magnetic field. The coil is made of 4 windings in parallel (1, 2, 3, 4). Average diameter: 2.17 m. **b** Drawing in profile of the device for exposure to a circular static magnetic field. 1: glass plate; 2: rubber pierce; 3: aluminium sheet; 4: coil; 5: wooden support; 6: cage

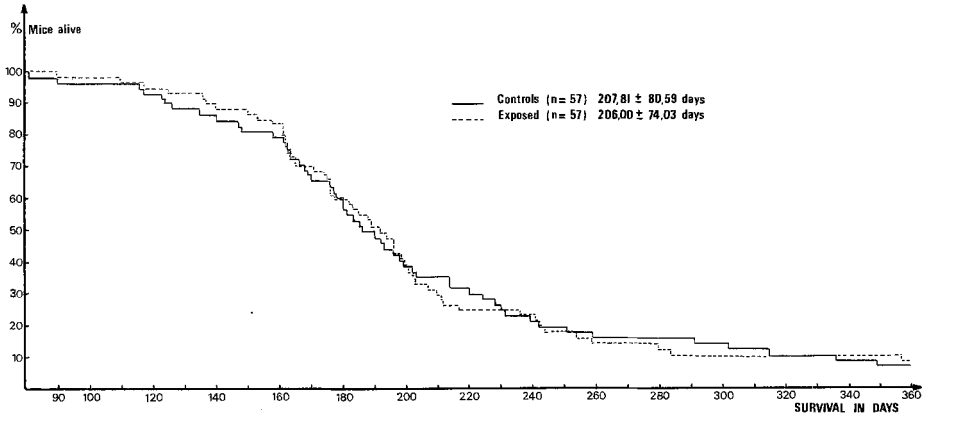

Fig. 2. Lifespans of female AKR mice exposed continuously to a circular static magnetic field (pecked line) and of their controls (full line). Maximum field strength: 4.6 mT

Table 1. Averages of the weights of the thymus and the spleens of the control mice and of the mice exposed to a circular SMF with standard deviations (maximum field strength = 4.6 mT)

	Thymus (mg)	Spleens (mg)
Controls	637 ± 330	370 ± 205
Exposed	616 ± 329	397 ± 237

Exposure to an uniform SMF.

The lifespans are represented in Fig. 3. After the 200th day the survival curves of mice exposed to 600 mT or to 800 mT tends to separate from the survival curves of the mice exposed to 400 mT and of the controls. Moreover the average lifespans of mice exposed to 600 mT or to 800 mT are 221.71 ± 106.67 days and 234.79 ± 100.27 days respectively.

There is no difference between the control group and the mice exposed to 400 mT. The difference between the control group and the mice exposed to 600 mT or 800 mT put together is significant ($P < 0.05$) according to the log rank-test. Exposure to uniform MF of 600 mT or 800 mT has led to a longer average lifespan.

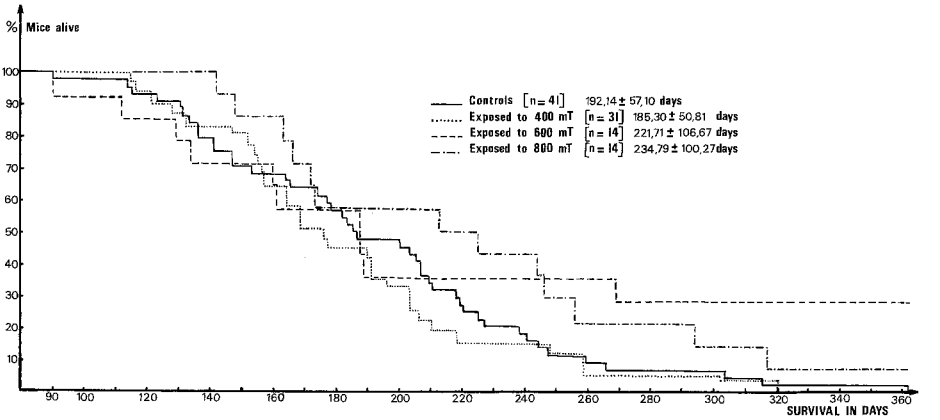

Fig. 3. Lifespans of female AKR mice exposed to a static uniform magnetic field of 400 mT (dotted line), 600 mT (pecked line), 800 mT (dotted-pecked line) and of their controls (full line). Length of exposure: 2 h a day, 5 consecutive days a week

The averages of the weights of thymus and spleens are reported in Table 2.

There is no significant difference between the average weights of the spleens of the three groups. The average weight of the thymus of mice exposed to 600 or 800 mT is lower than the average weight of the thymus of the control group and of the mice exposed to 400 mT. The average weight of the thymus of the two subpopulations 600 or 800 mT put together is 427 ± 314 mg; according to the student test it is significantly different from the average weight of the thymus of mice exposed to 400 mT ($P = 0.05$).

Table 2. Averages of the weights of the thymus and the spleens of the control mice and the mice exposed to a uniform SMF of 400 mT or 600 or 800 mT with standard deviations

	Thymus (mg)	Spleens (mg)
Controls	574±283	406±231
400 mT	616±285	455±250
600 mT	434±332	379±207
800 mT	421±310	385±211

Exposure to a non-uniform SMF

The lifespans are represented in Fig. 4, the averages of the weights of the thymus and the spleens are reported in Table 3.

Exposure to the MF resulted in no significant difference.

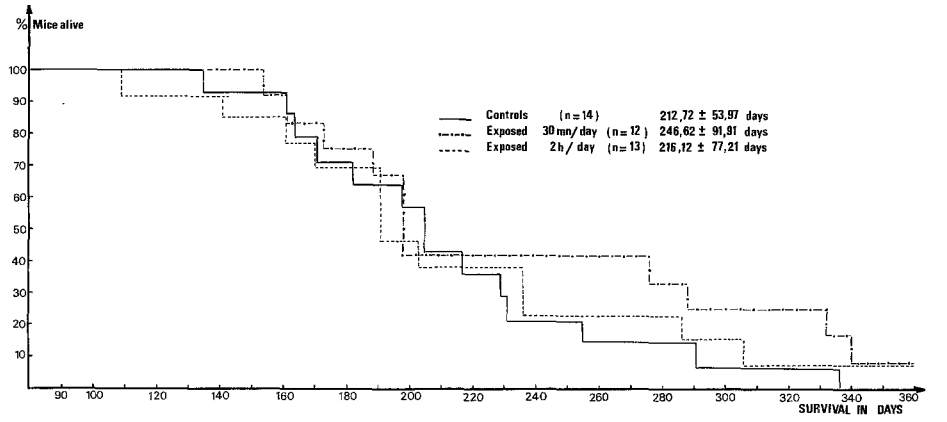

Fig. 4. Lifespans of female AKR mice exposed to a static non-uniform magnetic field of 900 mT, 30 mT.cm^{-1}, 5 consecutive days a week, 30 min a day (pecked line) or 2 h a day (dotted line) and their controls (full line)

Table 3. Averages of the thymus and the spleens of the control mice and of the mice exposed to an non-uniform SMF for 30 min a day or 2 h a day with standard deviations

	Thymus (mg)	Spleens (mg)
Controls	549±272	309±191
Exposed 30 min/day	464±367	348±362
Exposed 2 h/day	573±257	418±268

Discussion

Repeated exposure to a uniform SMF of 600 mT or more has lead to a significantly longer survival time. According to Fig. 3 this phenomenon af-

fects about 50% of the exposed population. For the first 50% the mortality graphs of the control group and of the exposed mice are similar. So the population does not appear to be homogeneous with regard to the SMF.

A correlation between the lengths of survival of mice and the weights of the thymus does not seem exist. But if we considered the thymus of the mice exposed to 600 or 800 mT which died before or after the 200th day – that is to say on both sides of the point where the slope of the survival curve changes – the average weights are 528 ± 327 mg and 281 ± 294 mg respectively.

The lifespan of the population exposed to an non-uniform static MF 30 min a day is analogous at those of mice exposed to 600 or 800 mT. But the lifespan of the population exposed 2 h a day does not differ from the lifespan of the controls. Is this apparent difference between the exposed population due to the different length of exposure or is the 2 h exposed group not important enough to let 2 different sensitivities to the MF appear?

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