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THE BIOLOGICAL EFFECTS OF IMPLANTED MAGNETIC FIELDS PART 1. MAMMALIAN BLOOD CELLS

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Introduction

The purpose of this study was to determine what effects magnetic fields from implanted cobatl-samarium magnets have on the blood of mammals.

The biological effects of magnetic fields have been investigated for some time now and the literature contains many references on the effects of magnetic fields on mammalian blood. (Barnothy, 1964; 1969). The usual method of research in biomagnetics has involved placing the study animals into a magnetic field different to the geomagnetic field. The results of such experiments by Likhachev (1969) include alterations in the E.S.R.* Barnothy (1964) found changes in the white blood cell count in mice. Hackel et. al. (1964) showed that strong magnetic fields caused agglutination of human erythrocytes. Russian researchers, Gnevyshev and Novikova (1972), hypothesized that geomagnetic storms may be responsible for increased mortality from myocardial infarctions by inducing fibrinolysis of the blood. Their conclusions were not supported by a long-term study on solar activity and mortality in the United States by Feinleib, Rogot and Sturrock (1975). Viktora, Fiala and Petz (1976) found that magnetic fields of 180-200 gauss had no effect on the numbers or proliferative capacity of the haematopoietic stem cell of mouse bone marrow over three to five month periods of exposure. Pauling (1977) found that oxyhaemoglobin in blood or in solution at 20° has zero magnetic moment.

Becker (1970 wrote of the discovery of a super-permanent magnetic alloy of cobalt and samarium (Co_5Sm) which has provided dentistry with a possible supplement to the presently available mechanical force systems used in prosthetics and orthodontics. Laboratory analysis by Cerny (1978) has shown that the magnetic energy provided by cobalt-samarium magnets is sufficient to retain dental prostheses and to move teeth orthodontically. However, Barnothy (1964; 1969) and others have shown that the introduction of fixed magnetic fields into the mouth may produce harmful effects upon the blood. Before any clinical trials are commenced on humans, animal trials should first determine if implanted magnetic fields are biologically harmless over a suitable range compatible with human usage.

There have not been any reports to date in the literature on the effects of implanted magnetic fields on the blood of mammals. It is not known if there is an implant magnetic flux density threshold above which harmful effects are produced in the blood, and below which acceptable biological tolerance occurs.

Materials and Method

Thirty-six adult S.D. (Sprague-Dawley) albino rats, approximately six months old and in good health, consisting of 18 males and 18 females were separated into three

* E.S.R — Erythrocyte sedimentation rate.

groups and under ether inhalation anaesthesia, implants of magnetic and non-magnetic control materials wrapped in gold foil, were placed at different sites in the body.

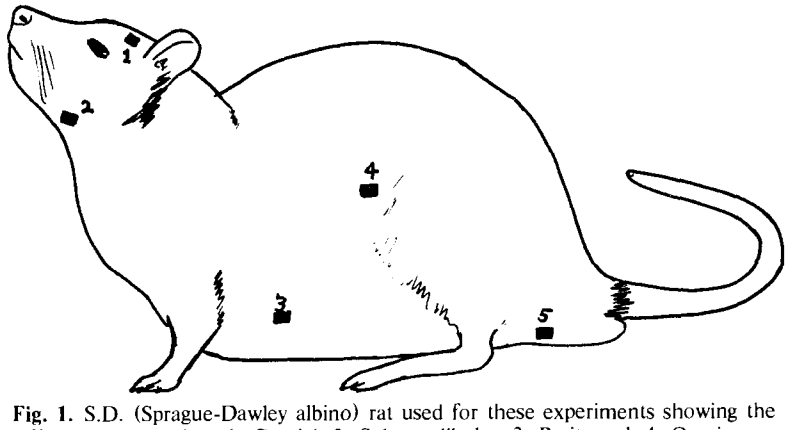

Fig. 1. S.D. (Sprague-Dawley albino) rat used for these experiments showing the different implant sites: 1. Cranial; 2. Submandibular; 3. Peritoneal; 4. Ovaries o; 5. Testes o.

The implants were approximately 1.5 cm thick by 2.5 mm in diameter. The magnetic field strengths from the magnetized implants were approximately:

95 millitesla* at 1 mm
40 millitesla at 2 mm
10 millitesla at 3 mm
.04 millitesla at 30 mm

The magnetic flux density decreases by the inverse of the sqaure of the distance from the magnet $F = \frac{m^1 m^2}{d^2}$

(F = magnetic flux density, m = magnetic pole strength, d = distance from magnet)

The implants were wrapped in gold foil to allow minimal contact of the implant alloy with the tissue fluids. Some degree of exposure of the cobalt samarium alloy to the tissues would be expected to occur should this alloy be used in humans for long periods of time.

Group A — consisted of eight male and eight female rats.

It was divided into three subgroups:

A1. Magnetic implant of cobalt-samarium (four males and four females).
A2. Non-magnetic implant of cobalt-samarium (two males and two females).
A3. Control implant of inert aluminium alloy (two males and two females).

Each rat had three implants placed, one at each of the following sites (Fig. 1):

1. Subcutaneously over the brain
2. Intra-peritoneal
3. Near the gonads.

* Millitesla — unit of magnetic flux density. The Geomagnetic field flux density is approximately 0.05 millitesla.

Group B — consisted of three male and three female rats.

Each animal had three magnetized cobalt-samarium implants placed in similar sites to Group A.

Group C — consisted of eight male and eight female rats.

Six male and six female rats each had two implants placed near the submandibular glands (Fig. 1). In each case, one implant was magnetized cobalt-samarium while the other was non-magnetized cobalt samarium or aluminium alloy. One female rat died during the operation.

Two rats, one male and one female each had four implants inserted, two magnetized and two non-magnetized of cobalt-samarium alloy. Two implants were placed near the submandibular gland and two were placed subcutaneously, one on either side of the abdomen. These implants were not wrapped in gold foil.

A control group of one male and one female rat had two non-magnetized implants placed subcutaneously. The male rat died during the operation.

The rats were housed in groups of three or four in rectangular plastic cages with sawdust on the floor and covered with a heavy gauge wire lid. They were all kept in the same room to avoid any environmental difference.

Their diet was strictly controlled in its content but not in its quantity. Water was freely available at all times. The rats were fed and observed on a daily basis by the author and their cages were cleaned every three days. Some breeding with selected magnetic and control rats was also carried out.

At the conclusion of the experiments, the rats were anaesthetised via ether inhalation and a jugular vein was exposed by careful dissection of the lower neck region. Blood was aspirated from the jugular vein using a 10 ml. disposable syringe and short 22 gauge needle. The amount of blood taken was always in excess of 3 mls. and this was used to fill 2.5 ml blood collection capsules which contained anticoagulants. The filled blood capsules were then gently agitated to ensure thorough mixing of the anticoagulants with the blood. The rats were then sacrificed with an overdose of ether anaesthetic and weighed before the implants were surgically removed with surrounding tissue for histological analysis.

The fresh blood samples were taken to the Royal Prince Alfred Hospital (Sydney) Haematology Department where blood slides were prepared for blood cell counts and microscopic analysis. The remaining blood was analysed in a blood analysis computer (COULTER-S) for the following measurements.

1. W.B.C. White blood cell count x 10⁹/1
2. R.B.C. Red blood cell count x 10^{12}/1
3. Hgb Haemoglobin g/dl
4. P.C.V. Packed Cell Volume (haematocrit value) 1/1
5. M.C.V. Mean Cell Volume fl
6. M.C.H. Mean Cell Haemoglobin pg
7. M.C.H.C. Mean Cell Haemoglobin concentration g/dl
8. Platelets x 10⁹/1
9. Polychromasia Colour of cells

Any blood samples which contained clots were discarded from the computer analysis. The rats from Groups A and B were sacrificed 7½ months after the implantation operation while those in Group C were sacrificed after 3½ months. The blood slides which were prepared from each blood sample were stained with May-Grunwald-Geimsa before a blood cell analysis was done.

100 white blood cells were counted and grouped in percentages as:

1. segmented neutrophils
2. lymphocytes
3. monocytes
4. eosinophils
5. basophils

Results

Thirty-six rats were used at the beginning of the experiment and included 26 study rats and 10 control rats. Of these, six study rats and two control rats died before the termination of the experiment. The reasons for their deaths were not attributed to the implants.

Blood analyses were obtained from 23 rats 16 study rats and 7 controls. The results of the blood analyses are shown in Table 1. The data from groups A, B and C were arranged in their respective groups. Statistical analyses were done and averages were compared with normal values shown by Wintrobe (1974) (Table 2.).

The blood slides showed that plate-lets were in more abundance than for humans. This was true for all slides examined. Another feature of the rats' blood in comparison with human blood was the polychromasia factor. The rats' blood consistently showed high polychromasia indicating a high number of young red blood cells. This was again true for all slides examined.

The cobalt-samarium alloy used as implants showed marked corrosion and weakening of the magnetic field strength after being implanted for six months or more.

Discussion

The results showed no adverse effects from the implanted magnets upon the blood cells of rats. There were discrepancies in the white blood cell analyses for the neutrophil and lymphocyte percentages of the control rats but not the experimental rats. The reason for this is not known. The histologic blood cell analysis showed no abnormalities within the different rat groups and an independent pathologist who viewed the blood slides could not differentiate between the control groups and the experimental groups.

The radius of the magnetic field generated by the implanted cobalt-samarium magnets was approximately three centimetres before it had become attentuated to the earth's magnetic field. Those rats with three magnetic implants would have had most of their tissues within a weak and fixed magnetic field covering a gradient of approximately 90 to 0.05 milliteslas. The use of similar magnets in human beings could be expected to cause no adverse effects on the blood cells. However, this does not necessarily apply for larger and more powerful magnetic fields. Barnothy (1974) wrote on biomagnetic effects and indicated that there is a magnetic flux density threshold beyond which tissue damage will occur. As yet, this threshold for mammalian blood is unknown. Nor is it known if different mammalian species will be effected in the same way by similar magnetic fields. Further research and experimentation with these magnets on humans would be greatly enhanced if the biological tolerance levels of magnetic fields were known.

Experiments of a similar nature are at present underway using larger cobalt samarium magnets which are comparable with magnets of a size suitable for retaining

TABLE 1. Blood analysis of the rats used in the experiment. The blood factor readings were obtained from a Coulter-S blood analysis computer. Blanks in the table indicate death before completion or unusable samples due to clots.

		BLOOD ANALYSIS													
GROUP		WBC	RBC	Hgb	PCV	MCV	MCH	MCHC	Pl	Pc	S.N.	Ly	E.	M.	WCC
A	1														
♂	2	8.2	7.99	15.1	.435	55	18.9	34.6	N	N	43	55	2		100
	3	7.6	8.77	14.9	.433	50	16.9	34.2	N	N	28	65	3	4	100
MAGNETIC	4	8.5	8.63	15.6	.451	53	18.1	34.6	N	N	22	75	2	1	100
Co_5Sm	5	8.7	7.05	13.8	.408	59	19.5	33.6	N	NA	NA	NA	NA	NA	
	6														
♀	7														
	8														
NON MAGNET	9														
♂	10	5.5	8.33	14.5	.417	51	17.4	34.7	N	N	41	57	1	1	100
Co_5Sm	11	6.1	7.29	14.0	.422	59	19.2	33.1	N	NA	NA	NA	NA	NA	
♀	12	10.2	6.49	13.1	.372	58	20.1	35.1	N	N	54	45		1	100
♂	13														
ALLOY	14	5.4	7.76	14.3	.415	54	18.3	34.2	N	N	39	59	1	1	100
	15	5.1	7.07	14.1	.409	59	19.9	34.4	N	N	47	52		1	100
♀	16	6.6	7.57	14.7	.421	56	19.3	34.9	N	N	39	59	2		100
B	17														
♂	18														
MAGNETIC	19	10.6	8.61	15.1	.442	52	17.4	33.9	N	N	36	61	3		100
Co_5Sm	20														
♀	21	6.1	6.2	13.5	.388	63	21.8	34.9	N	N	26	70	3	1	100
	22	5.4	6.44	14.7	.434	69	22.7	33.8	N	N	38	60	2		100
C	23*	8.7	8.11	15.7	.444	55	19.1	35	N	N	22	76	2		100
	24	6.3	8.16	15.7	.432	53	19.1	36.1	N	N	24	73	2	1	100
♂	25	10.9	8.92	15.5	.441	50	17.3	35.0	N	N	28	71		1	100
MAGNETIC	26	14.1	8.95	16.0	.444	50	17.7	35.7	N	N	16	82	1	1	100
Co_5Sm	27	12.5	9.19	16.4	.463	51	17.7	35.0	N	N	23	75	1	1	100
	28														
	29														
	30														
♀	31	9.1	8.61	15.9	.458	54	18.3	34.3	N	N	15	84	1		100
	32	4.7	7.51	15.3	.434	59	20.1	34.9	N	N	24	73	3		100
	33	8.2	8.03	15.3	.429	54	18.9	35.5	N	N	14	85	1		100
	34*	9.2	7.75	15.6	.45	59	19.9	34.3	N	N	14	83	2		100
CONTROLS	35														
♀	36	6.1	8.57	16.1	.454	54	18.5	35.0	N	N	43	54	3		100

N = Normal

NA = Not Applicable

* No gold foil over the implants

TABLE 2. Blood analysis comparisons between the magnet and control rats. The normal range is listed in the first column. T tests were also done between the magnet and control groups.

BLOOD CELL FACTOR	NORMAL MEANS (WINTROBE 1974)	MAGNET GROUP MEAN	MAGNET GROUP S.D.	CONTROL GROUP MEAN	CONTROL GROUP S.D.	SIGNIFICANCE LEVEL
W.B.C.	14.7 ± 7	8.68	2.427	6.43	1.527	0.025 to 0.01
R.B.C.	8.05 ± 1.45	8.06	0.874	7.23	0.814	0.025 to 0.01
Hgb.	13.8 ± 0.8	15.26	0.760	14.4	0.907	0.025 to 0.01
P.C.V.	0.413 ± 0.019	0.437	0.018	0.416	0.024	0.025 to 0.01
M.C.V.	57 ± 8	55.38	5.26	55.86	3.024	0.450 to 0.40
M.C.H.	19 ± 3	18.96	1.599	18.96	0.952	> 0.450
M.C.H.C.	32 ± 2.7	34.7	0.693	34.5	0.691	0.300 to 0.250
WHITE BLOOD CELL						
Seg. Neut.	15.5 ± 11.5	24.87	8.78	43.83	5.81	> 0.005
Lympho.	80 ± 10	73.2	9.182	54.33	5.34	> 0.005
Eosin	1.3 ± 0.8	2.0	0.926	1.75	1.332	0.35 to 0.30
Mono.	3.5 ± 2.5	1.4	1.242	1.0	0.57	0.25 to 0.20

dental prostheses in humans. The cobalt samarium corrosion and magnetic flux density decay which occured during this study indicates the need of complete isolation of the magnet alloy from the tissue fluids. This could be achieved by some form of thin inert impervious coating around the magnet alloy.

Conclusions

The results of these experiments suggest that implanted magnets which produce a maximum magnetic flux density of 95 milliteslas and which do not exceed three in number, will not produce harmful effects upon the blood cells of rats.

Cobalt-samarium (Co_5Sm) magnets corrode and undergo marked magnetic decay if implanted in mammalian tissues for six months or more. If this magnetic material is to be used in a corrosive fluid environment, the alloy should be completely isolated from such an environment with a thin tough impervious and inert material.

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