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ON THE EFFECT OF ULTRASONIC VIBRATIONS ON THE BLOOD

Following is a translation of an article by M. I. Gurevich and M. G. Sirotina in Fiziologichnyy Zhurnal (Physiology Journal), Vol. VI, No. 1, 1960, pages 73 to 77.

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Investigations devoted to a study of the influence of ultrasonic vibrations on the blood have been carried out in two directions: some authors have studied directly the influence of ultrasonic vibrations on the blood elements in vitro, while others have studied the changes in the peripheral blood after exposure of the organism to ultrasonic vibrations ("sounding" the organism).

The hemolytic effects of ultrasonic waves in vitro were first studied by Dognon and Biancani (1927). Subsequently, numerous investigators confirmed this fact.

In 1936, Getzel showed that the hemolytic effect caused by ultrasonic waves depends on the concentration of the erythrocytes: the higher the red cell count, the less destructive the effects of ultrasonic.

Shener (1948) also indicated that the destruction by ultrasonic vibrations of a suspension of erythrocytes depends on the concentration of the cells and the power of the ultrasonic vibrations.

The hemolytic influence of ultrasound is apparent within several seconds after the onset of "sounding" (Leman, 1949).

Bejdl (1950), on the basis of his studies, pointed out that laking of the blood may be produced with a 25-minute "sounding". Stuhlfauth and Wuttge (1950) used "sounding" of leukocytes to produce a heavy granularity in the cytoplasm of the eosinophils.

Lehmann, Becker, and Otto (1952) also observed changes in the structure of the eosinophils upon "sounding" blood.

Onanov (1957) reports that the "sounding" of whole stabilized blood of human beings with ultrasonic vibrations with a frequency of 500 c/s at an intensity of six wt/sq cm causes, within 1.5 min, a lysis of leukocytes, and later,

hemolysis of the formed elements of the blood. According to their findings, the most resistant with respect to ultrasound are the erythrocytes, and the most sensitive are the granulocytes.

Changes in the peripheral blood after exposure to ultrasonic vibrations have been studied very little in the living organism. Dognon and Biancani (1932) did not note changes in the peripheral blood upon exposure of the organism to ultrasound. Gaden (1952), after "sounding" 15 patients with therapeutic doses of ultrasound, did not discover any regular changes in the peripheral blood: in some cases the number of leukocytes increased, in others it decreased. Sometimes there were no digressions whatsoever in the elements of the hemogram. In the bone marrow, there was a certain increase in the number of cells of the eosinophilic series.

Eritavi, Onanov, Georgadze, and Akhmeteli (1955), on the basis of their investigations of two dogs and five rabbits, concluded that the effects of ultrasound on different parts of the brain and spinal cord of the dog and rabbit result in changes not only at the site of "sounding", but also cause marked reactions on the part of the peripheral blood.

Our own studies were devoted to the influence of ultrasonic vibrations on the blood in vitro, and also to studies of the changes in the morphologic composition of the peripheral blood after "sounding" parts of the abdomen in animals.

In the first series of studies, the blood taken from different animals was stabilized with a five-percent solution of sodium citrate. Erythrocyte and leukocyte counts were made on the diluted blood. After this, the blood was poured into specially prepared glass cylinders, the bottoms of which were drawn out into a fine cone, and subjected to the action of ultrasonic vibrations with a frequency of 800 c/s and an intensity of 0.2 wt/sq cm (in five cases) and 3.5 wt/sq cm (in three cases). After five, ten, 15, and 30 minutes, portions of blood were removed for determination of erythrocyte and leukocyte counts.

Our studies showed (Table 1) that, even within five minutes, at an intensity of "sounding" of 0.2 wt/sq cm, the erythrocyte counts were reduced (no changes were noted in the leukocyte counts). After ten, 15, and 30 minutes, reduction in the erythrocyte counts continued; the number of leukocytes noticeably declined, however, only in one study after a 30-minute "sounding."

Table 1

The influence of ultrasonic vibrations on the blood
Minutes after "sounding"

No. of study	Conditions of "sounding" in wt/sq cm	Animal studied	Minutes after "sounding"									
			Before "sounding"		5 xb.		10 xb.		15 xb.		30 xb.	
			Erythrocytes	Leukocytes	Erythrocytes	Leukocytes	Erythrocytes	Leukocytes	Erythrocytes	Leukocytes	Erythrocytes	Leukocytes
1	0.2	rabbit	5.10	7800	4.44	7700	3.80	7800	3.2	7400	2.80	7400
2	0.2	"	4.54	8200	4.30	7740	3.90	7100	3.6	6440	3.40	6200
3	0.2	"	5.36	3600	4.70	3600	4.34	3200	4.3	3200	4.20	2700
4	3.5	"	5.40	3200	1.20	1600	4.00	200	310 K.A.	150	isolated	isolated
5	3.5	"	6.10	5200	2.40	2700	1.08	750	500 K.A.	230	"	"
6	3.5	dog	5.30	5100	3.18	4100	0.90	500	-	-	"	"
7	0.2	rat	6.10	14000	5.80	14000	5.61	14000	5.6	13800	4.80	13800
8	0.2	"	5.60	12400	5.10	12400	4.99	12200	4.9	1200	4.58	11700

With an intensity of "sounding" of 3.5 wt/sq cm, changes were more obvious. In these studies, within five minutes there was already a significant reduction in the erythrocyte and leukocyte counts, and after 30 minutes there was almost complete hemolysis of erythrocytes and destruction of leukocytes; only isolated, individual formed elements could be seen in a given microscopic field.

In another group of studies, we "sounded" regions of the abdomen in rats and rabbits and studied the changes in the morphologic composition of the blood. These experiments were run on 20 rats and four rabbits.

In one series, ten rats were "sounded" with a frequency of 800 c/s at an intensity of 0.5 wt/sq cm for three minutes. The blood for erythrocyte and leukocyte counts was taken prior to exposure, and one hour, two days, six days and 12 days after "sounding".

As can be seen from Table 2, one hour after "sounding" there were no essential changes in the erythrocyte counts; the leukocyte counts in some instances (nos. 1, 3, and 5) did not change, but in others (nos. 2, 4, 6, and 7) showed a slight reduction. After two days, the blood showed more significant changes. The leukocyte count showed a definite tendency toward reduction. After six days, the leukocyte counts, on the contrary, in many of our individual studies, increased beyond the original level.

Changes in the erythrocyte counts, as previously, were not striking.

Table 2

Changes in the composition of the blood upon "sounding" parts of the abdomen of rats with ultrasonic vibrations with a frequency of 800 c/s and an intensity of 0.5 wt/sq cm

No. of study	Before "sounding"		Time after "sounding"							
	Erythrocytes in millions	Leukocytes	one hour		two days		six days		12 days	
			Erythrocytes in millions	Leukocytes	Erythrocytes in millions	Leukocytes	Erythrocytes in millions	Leukocytes	Erythrocytes in millions	Leukocytes
1	8.80	11800	8.82	11000	6.95	10000	8.20	13200	8.6	12000
2	8.60	16800	8.70	15000	8.0	14800	9.40	20600	8.9	16300
3	8.60	17400	8.63	16900	8.38	11400	8.40	17100	8.5	17800
4	8.55	20400	8.60	18700	8.60	16400	8.70	21300	8.6	20000
5	7.90	23600	8.0	2300	8.50	21200	8.0	22000	—	—
6	7.66	25300	7.51	21200	—	—	7.70	27800	7.8	24800
7	8.20	22200	8.0	20100	—	—	8.10	22000	8.1	21700
8	8.84	8900	—	—	—	—	8.23	9300	8.3	8000
10	6.91	12700	—	—	6.70	12000	—	—	—	—

On the 12th day the erythrocyte and leukocyte counts were approaching the original levels.

In the next series of studies, seven rats were exposed to ultrasonic vibrations for four minutes at an intensity of two wt/sq cm. All rats studied died within one hour and 30 minutes to one hour and 50 minutes after "sounding".

Studies of the blood were made prior to exposure and one hour after terminating the "sounding". Along with the erythrocyte and leukocyte counts, we likewise studied the hemogram (Table 3).

Table 3

Changes in the morphologic composition of the blood
of rats upon "sounding" for four minutes at an
intensity of two wt/sq cm

No. of study	Prior to "sounding"					One hour after "sounding"						
	Erythrocytes in millions	leukocytes	neutro-phils	eosino-phils	monocytes	lymphocytes	Erythrocytes in millions	leukocytes	neutro-phils	eosino-phils	monocytes	lymphocytes
1	6.40	17200	3268	516	1204	12212	6.39	14600	4088	584	730	9198
2	6.70	16200	2916	162	486	12636	6.72	15700	3925	314	628	10833
3	5.10	12400	2852	124	124	9100	5.02	12100	3630	121	242	8107
4	5.80	13200	1848	264	396	10692	5.80	12000	2160	120	360	9460
5	6.80	16100	3059	0	1127	11914	6.73	16100	4347	161	1288	10504
6	8.70	8810	528	0	352	7920	8.73	8600	774	172	430	7064
7	5.64	15300	1224	153	612	13311	5.70	15100	906	0	1208	12986

As can be seen from this table, we were unable to demonstrate regular changes in the composition of the peripheral blood. The erythrocyte counts exhibited no changes, and the total white cell counts changed in two animals but did not change in five. Upon analysis of the white cell differential, we discovered after "sounding" an increase in the absolute number of neutrophilic leukocytes and a reduction in the number of lymphocytes. No shift to the left in the differential count of the neutrophilic leukocytes was observed at any time. The absolute number of monocytes ordinarily increased. The number of eosinophils changed variously.

Upon "sounding" rats for five minutes at an intensity of 4.5 wt/sq cm, the animals died within two to three minutes after "sounding". Blood for analysis in these animals was drawn from the heart. As can be seen from Table 4, a marked reduction in the leukocyte counts was seen in all of these animals.

Table 4

Changes in the morphologic composition of the blood of rats upon "sounding" for five minutes at an intensity of 4.5 wt/sq cm

No. of study	Prior to "sounding"					One hour after "sounding"						
	Erythrocytes in millions	leuko-cytes	neutro-phils	eosino-phils	monocytes	lympho-cytes	Erythrocytes in millions	leuko-cytes	neutro-phils	eosino-phils	monocytes	lympho-cytes
1	7.65	19400	5072	194	392	13386	6.0	4400	440	0	224	3656
2	7.50	18000	1800	0	1020	15480	5.0	1400	168	0	98	1201
3	7.0	13800	552	276	1104	11868	6.1	5200	624	208	416	3952

Table 5

Changes in the morphologic composition of the blood of rabbits upon "sounding" for 30 minutes at an intensity of 3.5 wt/sq cm

No. of study	Hemoglo-bin in %	Prior to "sounding"						After "sounding"								
		Erythrocytes in millions	leuko-cytes	neutro-phils	basophils	eosino-phils	monocytes	lympho-cytes	Hemoglo-bin in %	Erythrocytes in millions	leuko-cytes	neutro-phils	basophils	eosino-phils	monocytes	lympho-cytes
1	—	5.3	5300	2750	0	212	106	2026	—	5.10	4700	3478	0	286	148	940
2	84	5.1	10600	3498	424	212	212	6254	84	5.20	10800	4320	432	108	1404	4536
3	78	5.72	12000	1800	120	120	1680	8280	78	5.75	12800	5760	—	—	1664	5248
4	81	6.02	13200	2640	132	264	—	10164	81	6.11	11800	3068	118	336	354	8024

Four rabbits were exposed to ultrasonic vibrations for 30 minutes at an intensity of 3.5 wt/sq cm. The blood was studied prior to exposure and one hour after "sounding" (Table 5).

As in the studies on the rats, no changes were evident in the erythrocyte levels one hour after "sounding".

Conclusions

(1) Upon "sounding" blood, stabilized with sodium citrate, with ultrasonic vibrations at an intensity of 0.2 to 3.5 wt/sq cm, there is observed a varying degree of destructive effect of ultrasound on the formed elements of the blood. The destructive effect of the ultrasonic vibrations is intensified upon increasing the intensity of "sounding".

(2) Upon "sounding" parts of the abdomen in rats for three minutes at an intensity of 0.5 wt/sq cm, the peripheral blood one hour afterward shows no detectable changes. On the second day, in a number of instances there are reductions in leukocyte counts, and on the sixth day the leukocyte counts in many cases show an increase. On the 12th day, the leukocyte counts revert to the original levels. The erythrocyte counts show no essential changes.

(3) After "sounding" rats with ultrasonic vibrations at an intensity of two wt/sq cm for four minutes, the animals die within 1.5 to two hours. No marked changes can be seen in the erythrocyte counts or the total leukocyte counts one hour after termination of "sounding".

(4) One hour after "sounding" rabbits for 30 minutes at an intensity of two wt/sq cm, there are no noticeable changes in the red blood or the total leukocyte counts. There is a slight reduction only in the absolute numbers of lymphocytes.

(5) The influence of ultrasonic vibrations at an intensity of 4.5 wt/sq cm directed at a portion of the abdomens of rats for five minutes leads to death of the animals within several minutes. Studies of the blood in these animals show marked reductions in the leukocyte counts. Reductions in the erythrocyte counts are also observed, but these are less pronounced.

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END