INFLUENCE OF ULTRASOUND ON THE PERMEABILITY OF THE BLOOD-EYE BARRIER AND OF THE REFRACTIVE MEDIA OF THE EYE

(UDC 612.844.014.45.084)

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Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 57, No. 5,
pp. 55-58, May, 1964
Original article submitted April 28, 1963

In the specialized literature dealing with the biological action of ultrasound there are no definite indications that the permeability of the blood-eye barrier or of the eye tissues alters under the influence of tolerable intensities of ultrasound. Only three communications touch on this problem [1, 2, 4], though the authors used an evidently damaging intensity of ultrasound which cannot be applied in practice.

The aim of the present investigation has been to study changes in the permeability of the blood-eye barrier and of the sorptive properties of eye tissues after irradiation of the eye with tolerable intensities of ultrasound; the results may be of significance in connection with ultrasound therapy in clinical ophthalmology.

EXPERIMENTAL METHOD

The experiments were carried out on 55 rabbits of a single strain, of approximately the same age and weight, and kept under similar conditions. In the experimental groups the left eye was irradiated with ultrasound at 800 kc and of intensity 0.4 W/cm^2 for five min. The course consisted of five daily irradiations carried out by a method we have developed and which excludes the influence of heat at the boundary between the vibrator and cornea. Five min after the last irradiation the animals received an intraperitoneal injection of sodium sulphate with labelled S($Na_2S^{35}O_4$), and of strength giving 5,000 impulses/min per g. To study the permeability changes the animals were killed 1, 4, 24, and 72 h later, both eyes were enucleated, and all the refractive media, and blood were investigated for S^{35} by means of a counter and a B apparatus. The mean value of the radioactivities was found and referred to 1 g of substrate. In the control experiments the radioactivity was measured at the same times.

TABLE 1. Changes in the Radioactivity of the Refractive Media of the Eye, and of the Blood, Under Normal Conditions

Substrate	Time (in hours)							
	1		4		24		7	
	Impulses/min/g	%	Impulses/min/g	%	Impulses/min/g	%	Impulses/min/g	%
Blood	4 127	100	147	3,3	131	3,1	114	2,5
Aqueous humor	3 316	80,4	1 642	39,8	213	5,1	191	4,5
Cornea	457	11,0	572	13,8	369	8,9	393	9,4
Crystalline lens	136	3,1	262	6,1	345	8,8	363	8,9
Vitreous humor	115	3,0	153	3,7	204	4,8	128	3,1

TABLE 2. Changes in the Radioactivity of the Refraction Media of the Eye After Irradiation by Ultrasound

Substrate	Time of investigation (in hours)							
	1		4		24		72	
	Impulses/min/g	%	Impulses/min/g	%	Impulses/min/g	%	Impulses/min/g	%
Blood	3 806	100	239	6,0	114	3,1	73	1,1
Aqueous humor	3 504	92,3	2 797	73,5	1 217	31,9	278	7,3
	3 208	86,3	2 785	73,1	1 137	29,8	238	6,2
Cornea	920	24,1	1 022	26,9	776	20,4	563	14,8
	815	21,4	934	24,3	694	18,2	546	14,3
Crystalline lens	182	4,8	503	13,2	515	13,5	506	13,3
	160	4,2	456	11,9	440	11,5	475	12,4
Vitreous humor	145	3,8	318	8,3	334	8,9	149	3,9
	103	2,7	169	4,4	286	7,5	139	3,6

Note. The numerator indicates the radioactivity of the media of the irradiated eye, the denominator indicates the radioactivity of the opposite (nonirradiated) eye.

EXPERIMENTAL RESULTS

The control experiments showed there were no differences in the distribution of S^{35} as between the right and left eyes. Therefore, in Table 1 we give results applying to both eyes and expressed as the mean amount of radioactivity (impulses per min, and as a percentage of the activity of the blood).

From Table 1 it can be seen that 1 h after the injection of a maximal dose of radioactive sulphur there was a certain radioactivity in the blood, somewhat less in the fluid of the anterior chamber, still less in the cornea, and least of all in the crystalline lens and vitreous humor.

By the start of the fourth hour there was a marked reduction in the radioactivity in the blood and of the fluid in the anterior chamber and an increase in the amount of S^{35} in the cornea, lens, and vitreous humor.

After 24 h the amount of radioactivity in the blood way very low, and there was a reduction in the amount of S^{35} in the aqueous and in the cornea. At the same time there was a marked increase in the radioactivity of the lens and of the vitreous.

After 72 h the amount of S^{35} in the blood had fallen to 2.5%, in the anterior chamber it was 4.5%, in the cornea 9.4%, in the crystalline lens 8.9%, and in the vitreous it was 3.1% of the amount present after 1 h.

Having studied the changes in the radioactivity of the eye media under normal conditions we then proceeded to determine what influence there was on the permeability of the blood-eye barrier and of the refractive media by a course of ultrasound.

Table 2 shows that ultrasound exerts a marked influence of the permeability of the blood-eye barrier and on the sorbtive properties of the refractive media of both the irradiated and the opposite eye.

One hour after the last irradiation the amount of S^{35} in the fluid of the anterior chamber of the irradiated and of the opposite eye exceeded the value in the controls, the two amounts being 92.3 and 86.3%. Particularly marked differences were found in the period between 4 and 24 h. In the control experiments at these times was a reduction in the radioactivity of the aqueous, but in the experiments with ultrasound irradiation the activity of the fluid of the anterior chamber remained at quite a high level (73.5 and 31.9%). In the opposite eyes there was also a high S^{35} content (73.1 and 29.8%). Only by the beginning of the third day did the radioactivity of the aqueous humor approximate the control values.

Under the influence of ultrasound the sorptive properties of the cornea of both the irradiated and of the opposite

eye were considerably enhanced. The course of irradiation also exerted a marked influence on the sorptive properties of the lens. A comparison of the results obtained and the control values shows that under the influence of ultrasound the sorptive properties of the lens increased on average by $1\frac{1}{2}$ - 2 times and remained at a raised level for the whole period of observation.

The ultrasound causes marked changes in the permeability of the crystalline lens, although these changes are not as marked as in the other refractive media.

The results we obtained on the increased permeability of the blood-eye barrier and of the refractive media of the eye may to some extent be related to the depolarizing action of ultrasound on hyaluronic acid [3], which is known to play an important part in the control of tissue permeability. Also the increased diffusion by the biological membranes under the influence of ultrasound is important. In addition an important part is played by the increased metabolic processes in the irradiated tissues. Finally we attribute considerable significance to the action of ultrasound on the nervous elements regulating vascular tone which in turn to a large extent determines the permeability of the blood-eye barrier.

Because the mechanism of the biophysical action of ultrasound is far from clear we cannot claim that our theoretical suggestions are the last word.

The analysis of the results we have obtained leads us to conclude that a course of irradiation of the eyes with ultrasound of therapeutically practicable intensity causes an increased permeability of the blood-eye barrier and of the refractive media, both in the irradiated and in the other eye.

SUMMARY

In experiments carried out on rabbits a study was made of the permeability of the blood-eye barrier and of the ocular refractive media after a course of irradiation with tolerable intensities of ultrasound. A marked increase of permeability was found; there was also an increase of the sorptive properties of the cornea, lens, and vitreous body, both in the irradiated and in the other eye.

LITERATURE CITED

1. N. N. Zaiko and S. M. Mints, In book: Programme and Abstracts of the 14th Scientific Session of the L. L. Girshman Ukrainian Scientific Research Institute of Eye Diseases. Khar'kov (1961), p. 17.
2. N. N. Zaiko and S. M. Mints, Byull. éksper. biol. (1962), No. 12, p. 32.
3. I. E. El'piner and S. M. Bychkov, Dokl. AMN SSSR (1952), 82, No. 1, p. 123.
4. W. Hallermann, A. Basch, and H. Ladeburg, Klin. Mbl. Augenheilk. (1951), Bd. 119, S. 401.

All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
