

# EFFECT OF ULTRAVIOLET IRRADIATION ON THE PERMEABILITY TO PROTEINS, RADIOCALCIUM, AND RADIOPHOSPHORUS OF THE CAPILLARIES OF THE ANTERIOR PORTION OF THE EYE

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(Received January 10, 1957. Presented by V. N. Chernigovsky, Member AMS USSR)

Apart from its theoretical interest, the study of the effect of ultraviolet radiation on the permeability of the capillary vessels of the eye may be of some importance clinically, since it is the cause of the condition known as electro-ophthalmia. The pathogenesis of this condition has not been sufficiently clarified. In particular, we were unable to find any references in the literature to capillary permeability in this disease.

Patients suffering from this condition complain of unbearable pain in the eyes, with photophobia and lacrimation. The symptoms appear after exposure of the unprotected eye to certain sources of light, such as the quartz-mercury vapor lamp in autogenous or arc welding, and in foundry practice during pouring of molten metals, etc. Electro-ophthalmia is analogous to snow-blindness, caused by the sun's rays in mountainous or polar regions. It is also encountered after exposure to the ultraviolet radiation released during nuclear explosions.

The present paper presents the results of a study of capillary permeability after ultraviolet irradiation of the eyes.

Capillary permeability was assessed from data for penetration of certain substances, viz., proteins,  $P^{32}$ , and  $Ca^{45}$ .

Capillary permeability can be assessed from the protein content of the aqueous humor, which is normally 200-300 times smaller than in the plasma of healthy animals. Augmentation of capillary permeability leads to a marked rise in the protein content of the aqueous humor. We estimated the protein content by a nephelometric method [11], especially adapted to this purpose.

Aqueous humor samples were taken by means of a fine hypodermic needle inserted into the anterior chamber.

Solutions of  $Na_2HP^{32}O_4$  and  $Ca^{45}Cl_2$  were injected into the marginal vein of the left ear of rabbits. The solutions were injected one immediately after the other: radiocalcium at a dosage level of 1500 imp./g, and phosphorus 200 imp./g. Puncture of the anterior chamber was effected one hour after the injections, and a blood sample was taken simultaneously from the marginal vein of the right ear. The content of both radioisotopes was determined in the same sample of aqueous humor (0.1 ml) or blood (0.01 ml), using filters [9]. The measurements were made in duplicate on dried films of the fluids. We first measured the total isotope activity, using an end-window counter. The measurement was then repeated, interposing a filter which cut off all the  $Ca^{45}$  radiation, and half of the  $P^{32}$  radiation. This filter consisted of 37 layers of aluminum foil. Counting of impulses was done in a B equipment, from an end-window counter in a lead chamber.

In view of the importance of vitamin C deficiency in the development of disturbances of vascular permeability, we also determined ascorbic acid in the aqueous humor.

Experimental electro-ophthalmia was produced by irradiating the left eye for 30 minutes, using mercury vapor lamps PRK-2 or PRK-4. The distance from the light source to the eye was 65 cm for PRK-2, and 40 cm for PRK-4. The right eye was shielded from the light of the lamps.

### EXPERIMENTAL RESULTS

Conjunctivitis and blepharospasm were observed on the next day, and also 2-3 days after irradiation. The sequelae of irradiation were no longer visible after 1-3 weeks.

The parameters measured varied parallel with the clinical changes. The protein content of the aqueous humor of the irradiated eye rose abruptly after 1-3 days (Table 1); Whereas the protein content of aqueous humor of control animals varied from 39 to 84 mg-% [7], after irradiation the range was 200-1840 mg-%.

TABLE 1

Protein and Ascorbic Acid Contents of the Aqueous Humor (mg %) after Irradiating the Left Eye, from a Quartz-Mercury Vapor Lamp

No. of rabbit	Interval bet. irradi. and puncture (days)	Protein		Ascorbic acid	
		right eye	left eye	right eye	left eye
1	1	26	210	17.2	10.2
2	1	40	200	17.3	15.0
3	2	52	450	13.8	6.6
4	2	65	390	24.9	17.1
5	2	49	250	25.7	21.3
6	2	22	240	15.6	13.0
7	3	62	1840	14.6	6.0
8	3	88	520	20.2	11.0
9	3	24	220	21.1	16.3
Average		48	480	18.9	12.9
5	18	59	48	27.4	27.1
4	20	49	35	23.2	22.8
0	23	38	43	18.4	18.7
3	41	45	47	11.8	9.3
7	44	76	72	25.3	26.0
1	45	52	55	18.0	16.9
Average		53	50	20.7	20.1

The protein content of the aqueous humor of the shielded eye did not rise (22-88 mg %).

After a lapse of 18-45 days from the beginning of the process the protein content of the irradiated eye was the same as for normal rabbits.

At the stage of maximum rise in protein content (1-3 days) the aqueous humor of the affected eye showed a higher concentration of radioisotopes than did the unaffected one (Table 2). The mean  $\text{Ca}^{45}$  content on the irradiated side was 136.8 imp./min., as compared with only 101.4 imp./min. on the opposite side. The corresponding values for  $\text{P}^{32}$  were 75.2 and 51.2 imp./min., respectively. The mean  $\text{P}^{32}$  activity of the blood of these rabbits was 148.6 imp./min (range 70-306.9 imp./min). The mean  $\text{Ca}^{45}$  of the blood was 131 imp./min (range 79-216 imp./min).

Our experimental findings are evidence of increased capillary permeability, for all the substances examined.

The ascorbic acid level fell in many cases to less than half the value found for the aqueous humor of the

TABLE 2

$P^{32}$  and  $Ca^{45}$  Activities of the Aqueous Humor (imp./min per 0.1 ml) after Irradiation of the Left Eye with a Quartz-Mercury Vapor Lamp

No. of rabbit	Interval bet. irradi. and puncture	Radiocalcium		Radlophosphorus	
		right eye	left eye	right eye	left eye
11	1 day	126.7	166.1	55.6	105.8
12	1 "	124.0	190.5	73.5	103.6
13	1 "	88.9	124.2	50.4	77.0
14	2 days	51.7	90.1	47.9	60.1
15	2 "	74.4	90.1	31.0	44.3
16	3 "	142.5	159.9	48.7	60.8
Average		101.4	136.8	51.2	75.2

intact eye, at the height of the rise in capillary permeability (Table 1). Such marked asymmetry is not encountered in healthy control rabbits [7]. Nor was it observed in these animals a few weeks after irradiation.

Since the quartz-mercury vapor lamp emits not only ultraviolet, but also visible light (49.5% of total emission [1]), we examined these fractions separately to ascertain whether visible or ultraviolet light was responsible for the changes observed. For this purpose we interposed a glass filter, which cut off all radiation of wavelength less than  $334 m\mu$ , between the light source and the eye.

TABLE 3

Protein and Ascorbic Acid Contents (mg %) of Aqueous Humor after Irradiation of the Left Eye with a Quartz-Mercury Vapor Lamp Through a Filter Cutting Off Ultraviolet Light

No. of rabbit	Interval between irradiation and puncture (days)	Protein		Ascorbic acid	
		right eye	left eye	right eye	left eye
17	1	44	31	17.4	19.0
18	1	36	39	19.8	20.2
19	2	34	43	38.9	40.0
20	2	34	37	16.4	17.0
21	3	42	32	14.6	17.0
22	3	44	27	20.2	18.2
Mean		39	35	21.2	21.9

We did not observe cases of electro-ophthalmia after exposure to the screened light, and we found no appreciable changes in the permeability of the capillaries of the eye to the substances studied. The results obtained from these experiments are presented in Tables 3 and 4.

These results are evidence that the changes in permeability of the capillaries following quartz-mercury vapor lamp irradiation of the eye were due to ultraviolet rays of wavelength less than  $334 m\mu$ .

The observed rise in protein content of the aqueous humor is due to raised capillary permeability. It cannot be ascribed to passage of proteins from the injured cornea to the aqueous humor, since electrophoresis

experiments have shown [10, 15] that the aqueous humor contains albumins and globulins, of which there is very little in the cornea [13].

We believe that the variations in vitamin C level observed after ultraviolet irradiation are also to a certain extent connected with disturbances of capillary permeability. The aqueous humor normally has an ascorbic acid content 10-30 times higher than that of blood plasma. If capillary permeability rises, vitamin C will diffuse out from the aqueous humor into the blood, as a result of which its concentration falls in the aqueous humor. Lowering of the vitamin C content of the anterior chamber leads, in turn, to still greater disturbance of capillary permeability.

TABLE 4

$P^{32}$  and  $Ca^{45}$  Activities of the Aqueous Humor (imp./min per 0.01 ml) after Irradiation of the Left Eye with a Quartz-Mercury Vapor Lamp Through a Filter Cutting Off Ultraviolet Light

No. of rabbit	Interval between irradiation and puncture (days)	Radiocalcium		Radiophosphorus	
		right eye	left eye	right eye	left eye
23	1 day	77.2	69.5	67.5	61.8
24	1 »	95.0	87.2	46.4	45.8
25	1 »	111.4	107.1	31.5	33.2
26	2 days	105.5	97.0	51.2	47.2
27	2 »	71.3	63.2	58.3	61.4
28	3 »	74.0	78.0	39.4	45.4
Mean		89.1	83.7	49.0	49.1

Ultraviolet irradiation of tissues leads to release of histamine and histamine-like substances [6]. The increased permeability of the capillaries of the anterior chamber observed by us may depend on the formation of such biologically active products. This view is supported by the observation that repeated subconjunctival injections of histamine lead to a raised protein content of the aqueous humor, with a simultaneous fall in its vitamin C content [4].

It may also be supposed that the changes observed by us are connected with stimulation of receptors (sensory terminations of the trigeminal nerve, for example). As is known, stimulation of this nerve causes a pronounced rise in the permeability of the capillaries of the eye [5], in particular to  $P^{32}$ ,  $Ca^{45}$ , and protein [3, 8]. Support is afforded to the reflex mechanism by the finding that the nature of the erythematous reaction to ultraviolet irradiation is greatly modified by narcosis [2], and that it proceeds differently in individuals suffering from various lesions of the central nervous system than it does in normal subjects [1].

## SUMMARY

Permeability of eye capillaries following irradiation by quartz-mercury lamp was studied by determining the permeation of protein  $P^{32}$  and  $Ca^{45}$  into the aqueous humor of the eye from the blood of rabbits. The content of proteins,  $P^{32}$  and  $Ca^{45}$  increased in the aqueous humor of the eye during marked manifestation of electrophthalmia. At the same time, the level of vitamin C was reduced. This showed that the permeability of eye capillaries was increased. One group of rabbits was irradiated by a quartz-mercury lamp protected by a filter which did not allow ultraviolet rays of the wavelength shorter than 334 mμ to pass. However, visible rays were not stopped by this filter. This was done since besides ultraviolet rays the quartz-mercury lamp irradiates numerous visible rays. Conditions of the latter experiment did not cause ophthalmia and had no effect on the above indices. Consequently, it was concluded that increased permeability of capillaries was caused by ultraviolet rays. A theory has been suggested to account for the reflex character of these changes and the significance of histamine in their development.

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\* In Russian.