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## Ultraviolet Irradiation of the Blood Stream in Septicemia.

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Eidinow<sup>1</sup> found that irradiation of the skin of rabbits with a "day-light lamp" emitting rays from infra-red to 2850 Å for 48 hours previous to infection with staphylococci afforded considerable protection, but that identical irradiation immediately following infection was without effect. He also reported<sup>2</sup> that irradiation of defibrinated blood *in vitro* with rays from a mercury vapor lamp down to 2200 Å caused a gradual destruction of the bactericidal power, reaching a maximum in 1½-2 hours, whereas injection of a few cc of this irradiated material resulted in an increase in the bactericidal power of the blood withdrawn from the circulation 1-3 hours after the injection.

There have also been a number of studies<sup>3</sup> of various effects of irradiation of the blood circulating through a quartz cannula inserted in an artery. These demonstrated a massive fall in blood pressure, concentration of the blood, and changes in the relative concentrations of various constituents of the blood, following intensive and prolonged irradiation. The present investigation was undertaken to determine the influence of mild ultraviolet irradiation of the circulating blood of rabbits on the course of an established infection with *Salmonella typhimurium* and as a comparison with *Salmonella paratyphi*.

In all of the experiments, young rabbits of about 2 kg were used after having been isolated for a month to eliminate sickness or pregnancy. The controls were subjected to the same operative trauma and injected with equal amounts of the same bacterial suspensions as were the animals to be irradiated. The strain of *Salmonella typhimurium* which was used was obtained from Lister Institute, whereas the *Salmonella paratyphi* was a strain recently isolated in Beirut. For each experiment, one loopful of broth culture was transplanted to a tube of broth to be incubated for 24 hours at 37°C. One loopful of this broth was then planted on an agar slant and incubated. After

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<sup>1</sup> Eidinow, A., *Brit. Med. J.*, 1929, **2**, 293.

<sup>2</sup> Eidinow, A., *J. Path. and Bact.*, 1930, **33**, 769.

<sup>3</sup> Falk, I. S., and Reed, C. I., *Am. J. Physiol.*, 1926, **75**, 616; Reed, C. I., *Am. J. Physiol.*, 1925, **74**, 518, 525.

24 hours, the slant culture was suspended in normal saline. The amount injected was calculated to be fatal within 48 hours; in only 5 cases out of 58 did the control live longer and none survived (Table I).

TABLE I.  
Effect of Irradiation of Infected Circulating Blood on Resistance of Rabbits.

	<i>S. typhimurium</i>		<i>P. paratyphi</i>	
	Irradiation	Control	Irradiation	Control
Total No. of rabbits used	36	30	48	28
No. surviving more than 48 hr	21 (58%)	4 (13%)	22 (46%)	1 (4%)
Avg survival time, in hr, of those which died	51	39	42	26
No. alive at end of 1 wk	3	0	5	0
Avg wt (g)	2069	2129	1917	2034

Under urethane anesthesia, the external jugular vein and common carotid artery were exposed and 10-15 mg of heparin per kilo of body weight was injected into the vein. This was followed by the fatal dose of bacteria. A system composed of a 45 mm quartz tube of 2 mm bore, connected at each end to glass cannulas of 1.2 mm bore by means of short rubber tubes, was then intercalated in the course of the artery. As soon as circulation through the quartz tube was observed to be satisfactory, irradiation was begun.

The source of light was a water-cooled Kromayer lamp operating at 4 amperes on 110 volts and giving between a first and a second degree erythema in 10 seconds' contact exposure. The irradiation time was varied from 4-15 minutes at 12-15 cm. Immediately after the irradiation the artery was ligated and the wound sutured.

The results given in Table I indicate that considerable protection is afforded to rabbits against otherwise fatal doses of either *Salmonella typhimurium* or *Salmonella paratyphi* by mild ultraviolet irradiation of the circulating blood, little difference being observed in the results obtained with the 2 organisms.

The maximum protection was obtained with 6 minutes' exposure at 12 cm. It should be stressed that the irradiation employed by us was very mild. Two rabbits subjected to 18 minutes at 15 cm (2-3 times the usual amount) suffered no observable ill effects and direct kymograph tracings of the blood pressure during the usual 6-8 minutes' irradiation at 15 cm showed no appreciable change. Furthermore, no sensitization seems to have occurred, since 2 of the rabbits were given second irradiations after a lapse of 2 hours with no harmful effects.

At least a part of the bacteria injected were present in the circulating blood at the time of irradiation, as shown by cultures taken from controls at 5 minutes, 2 hours, and 5 hours after the injection, all of which were strongly positive for the organism employed. Only a small fraction of the blood passing through the quartz tube at any one time could be reached by the ultraviolet rays, but the same blood passed repeatedly through the tube. We found that the total blood flow during 6 minutes' irradiation was about 600 cc, which is several times the total blood volume.

Autopsies were performed immediately after death and surviving animals were killed for autopsy after 2 weeks or more. None of the autopsies showed more than the usual variable sequelæ of the respective type of infection involved. All of the rabbits surviving more than one week showed persistently negative blood cultures.

In considering possible mechanisms producing the observed protection following irradiation of the blood stream, it should be noted that Guttmacher and Mayer<sup>4</sup> found that ultraviolet rays did not penetrate 1 mm of blood sufficiently to sterilize it. While it is possible that in our experiments sufficient bactericidal action did occur at the surface of the stream of blood passing through the quartz tube to influence the results obtained, the observations of Eidinow<sup>2</sup> on injection of irradiated blood, if confirmed, would suggest that the major effect was an indirect one, *i. e.*, the fraction of the blood which was reached by the ultraviolet rays entering the quartz tube may have acted like a small injection of irradiated blood in increasing the bactericidal power of the blood as a whole.

*Summary.* Mild ultraviolet irradiation of the circulating blood of rabbits which had been injected intravenously with doses of either *Salmonella typhimurium* or *Salmonella paratyphi* which were uniformly fatal to the controls resulted in a marked increase in survival time and in over 8% of the cases in recovery of the animal.

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<sup>4</sup> Guttmacher, M., and Mayer, E., *Am. Rev. Tuberc.*, 1924, **10**, 170.