

A COMPARATIVE ANALYSIS OF TROPHIC DISTURBANCES
CAUSED BY DENERVATION OR SINGLE-DOSE IRRADIATION
OF THE INTACT OR DENERVATED RABBIT EXTREMITY

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It is known that local irradiation of an extremity with roentgen rays can lead to the appearance of an ulcer on the irradiated portion [4, 7, 11]. Sometimes, following the irradiation, ulcers arise not only at the site of exposure, but also on the contralateral side. Thus, in the experiments of M. N. Livanov and N. S. Delitsina [8], 4 to 6 days after the appearance of an ulcer on the irradiated leg of a rabbit, a similar ulcer of smaller dimensions arose on the symmetrical portion of the opposite, unirradiated extremity. Control experiments, with protection of the contralateral extremity from dispersed roentgen rays, showed that the formation of ulcers is not the result of direct radiation. The ulcers arising on the unirradiated leg healed more rapidly than those situated at the site of irradiation.

In appraising the complex mechanism behind the genesis of trophic disturbances following irradiation, one may distinguish several units: 1) suppression of the process of physiological regeneration [1], 2) disturbance in the vascular permeability and the process of decomposition, arising in the epithelial and connective tissue [6], and finally, 3) injury of the nerve elements [2].

The arising of ulcers following transection of nerves was studied in detail in the works of A. D. Speranskii [12] and his students [9, 10, etc.]. A comparison of the dystrophic processes caused by irradiation with the changes arising after denervation points to their similarity. In both cases there occurs a depression of mitotic activity, depolymerization of nucleoproteids, disruption of the structure of epithelial and connective tissue, etc.

M. N. Livanov and N. S. Delitsina [8] showed that exposure to a dose of 5000 r leads to prolonged and complete disappearance of impulsion in the sensory cutaneous nerve endings. It may be assumed that the same thing occurs in other receptor fields of the irradiated extremity (proprioception, angioreception).

In line with the aforesaid, it may be postulated that the genesis of the dystrophic process in the irradiated area is a result of disturbances in innervation, caused by the penetrating radiation.

The purpose of this work was to carry out a comparative evaluation of ulcers caused by local, single-dose irradiation of a denervated or intact rabbit extremity.

EXPERIMENTAL METHOD

The experiments were carried out on 25 rabbits. The first series consisted of 10 rabbits, in which a denervated extremity was irradiated; the second (control)—8 rabbits, in which an intact extremity was irradiated; the third (control)—7 rabbits, in which denervation of the extremity was the only procedure performed. In all experiments, the work was carried out on the left posterior leg.

A single dose of radiation was administered by means of local exposure, delivering a dose of 5000 r of filtered roentgen rays to the foot (filters were 0.5 mm Cu plus 1 mm Al).

Almost complete denervation was attained by injecting 10 ml of a mixture consisting of 5 ml of a 0.5% solution of novocaine and 5 ml of a 96% solution of alcohol into the trunk of the sciatic nerve in the region of the thigh. In addition, approximately 10 ml of novocaine was injected into the muscle tendon sheaths. These procedures ensured prolonged suppression of the conduction in the reflex arc. The completeness of the block was controlled according to sensitivity to a needle prick.

EXPERIMENTAL RESULTS

In the first series of experiments, irradiation was carried out immediately after the denervation. In all the rabbits, ulcers appeared on the left posterior leg. Development of the dystrophic process occurred according to the type

TABLE 1. Degree of Ulceration of the Rabbit Extremities

Experimental series	Number of animals	Extremities	Degree of development of ulcers					Mean degree of injury	
			0	I	II	III	IV	%	relative units
First (denervation + irradiation)	10	Left, posterior	0	0	2	1	7	100	3.5
		Right, posterior	2	6	2	0	0	80	1.0
		Anterior	4	6	0	0	0	60	0.6
Second (irradiation)	8	Left, posterior	1	4	2	0	1	87	1.0
		Right, posterior	2	5	1	0	0	74	0.9
		Anterior	4	4	0	0	0	50	0.5
Third (denervation)	7	Left, posterior	0	3	4	0	0	100	1.5
		Right, posterior	4	2	1	0	0	42	0.6
		Anterior	6	1	0	0	0	14	0.1

described by M. N. Livanov and N. S. Delitsina [8]. The appearance of the ulceration was preceded by loss of the hair from the corresponding skin area. The area then became erythematous, with development of a dense infiltrate. The firm ulcer sometimes became watery. Despite careful handling, the ulcers easily became infected and suppurated, increasing in size. In certain cases the process of ulceration ended with the foot being torn off. During this period the general condition of the animal worsened. After 1-3 months many of the rabbits died.

To one or another degree, this picture was observed in all three series of experiments. The basic indices of the ulceration process were the time of arisal of the ulcer and the degree of ulceration. In order to characterize the degree of development of the dystrophic process quantitatively, we arbitrarily designated the firm ulcer as I, the watery ulcer as II, the suppurative one as III, and loss of the foot as IV; the absence of ulceration was designated as 0. The mean degree of injury, characterizing each series of the experiments, was arrived at by dividing the sum of all the degrees of injury to the cutaneous integument, including cases where injury was absent, by the number of animals in the group. Along with this evaluation of the trophic disturbances, we considered their classification according to the data of S. V. Gol'dberg [4], as well as M. N. Pobedinskii and Yu. K. Kudritskii [11]. However, since we recorded the disturbances only from the moment of appearance of the ulcer and up to loss of the foot, this appraisal does not reflect all stages of the trophic disturbance.

We considered not only the trophic disturbances arising on the left posterior leg, but also the appearance of ulcers on the right posterior leg and on the left anterior extremity, which were not subjected to direct exposure.

TABLE 2. Appearance Times of the Ulcers in Rabbits (in Days)

Rabbit No.	Extremities								
	left posterior			right posterior			anterior		
	experimental series								
	first	second	third	first	second	third	first	second	third
1	12	22	19	27	29	83	48	—	123
2	18	27	19	27	13	—	105	40	—
3	18	32	20	—	50	180	—	70	—
4	20	47	37	73	—	56	100	—	—
5	26	39	41	84	45	—	—	54	—
6	28	60	41	83	66	—	129	71	—
7	24	88	35	50	82	—	54	88	—
8	31	—		24	—		100	—	
9	64			84			—		
10	68			—			—		
Mean	40	45	30	57	50	106	90	65	123

Table 1 shows that the left posterior leg, where the procedures were localized, was injured in all cases except one, regardless of the character of the procedure. However, the degree of injury of this extremity was highest in the first series of experiments, where loss of the foot was observed in 7 rabbits. Then, according to the degree of injury to the left posterior leg, comes the series of experiments in which only denervation was performed, and finally, the series of experiments with irradiation. In the first series of experiments the result suggested a summation of the two actions: denervation and irradiation.

Pathological involvement of the right posterior extremity was approximately the same in the first two series of experiments, both in number of cases and degree of injury, and was half as great in the third series. The hypothesis is thus suggested that the transfer of trophic disturbances is dependent to a greater degree on irradiation than on denervation. This principle is seen even more clearly on analyzing the pathology of the anterior extremities (Table 1). It must be noted that only degree I ulceration was observed in the anterior extremities, while on the right posterior leg we also occasionally encountered degree II.

N. I. Grashchenkov [5], characterizing the development of the dystrophic process, noted that its transfer to other areas of the body depends on functioning of the central nervous system. Thus, with irradiation the central nervous system suffers to a greater degree than with denervation.

Table 2 shows that the appearance times of the ulcers on the left posterior leg was approximately the same with the different procedures: the difference between them was not statistically significant.

The ulcers usually appeared on the right posterior leg later than on the left. However, in 3 cases (in rabbit No. 8 of the first group, and in rabbits Nos. 2 and 7 of the second) the ulcers appeared earlier on the right posterior leg than on the left. Similar facts were described by M. L. Borovskii [3]; following transection and chronic irritation of the sciatic nerve of a rabbit, in certain cases he observed a more rapid development of ulcers on the extremity contralateral to the operated one. In this case, more manifest morphological changes were noted in the spinal cord on the side where the ulcers rose earlier.

The ulcers appeared later on the anterior extremities than the posterior, and only in one case (rabbit No. 7 of the second group) did the ulcers appear on the anterior extremities simultaneously with the ulcer on the left posterior leg. The impression is formed that extension of the dystrophic process to the anterior extremities is inhibited if irradiation is carried out after denervation. This is attested to by the statistically significant difference in the appearance times of the ulcers within the first and second series of the experiments (90 days against 65). After denervation, an ulcer appeared on the anterior leg in only one case, 123 days after the operation.

The experiments carried out showed that irradiation, against the setting of denervation, does not introduce changes in the rate of development of the dystrophic process. This supports the hypothesis of a disturbance in innervation associated with irradiation. This is further attested to by the approximately identical degree of ulceration seen on the irradiated or denervated extremity. However, the very serious trophic disturbances arising after irradiation of the denervated extremity indicate that with exposure to roentgen rays there is possibly either a supplementary irritating action on the nerve structures situated below the site of the alcohol-novocaine block, or destructive phenomena arising directly at the site of irradiation.

It is known that the intensity of the trophic disturbances characterizes, to a large degree, the source of the primary stimulus, while the distribution of their occurrence depicts the involvement of the central divisions of the nervous system. Our data shows that denervation or irradiation causes the same intensity of disturbances at the site of the procedure, and that their actions may be summated, but that dissemination of the disturbances is basically characteristic of irradiation. The role of the neural mechanisms clearly stands out in those experiments in which the ulcers arise on the unirradiated extremities. The appearance of symmetrical and distant ulcers after denervation alone is seen much more rarely. From this, the conclusion may be drawn that the action of irradiation possesses certain peculiarities, and cannot be completely likened to the individual phenomena of denervation. In this case, obviously, reflex influences play an important role.

SUMMARY

The following was recorded in 25 rabbits: the time of appearance and the extent of development of trophic disturbances after local x-irradiation, as well as after denervation or combined action of these two factors on the left posterior extremity. The appearance of ulcers at the site of action at about the same periods in all the animals suggests that dystrophic disturbances, following x-irradiation, were connected with the functional denervation. However, an analysis of the degree of ulcer development and of its spread to the other extremity indicates that the action of irradiation is not limited to the functional denervation alone, causing more considerable dystrophic disturbances.

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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.
