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Immunological reactivity of animals with tuberculosis under the influence of ionising radiation

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Abstract. Effective control of animal tuberculosis is possible only with a comprehensive examination of the biology of the pathogen, epizootiology, pathogenesis, prevention methods, economic and environmental factors that affect the course of the disease. It is known that radiation exposure leads to autosensitisation of the body by the breakdown products of its tissues and the development of non-specific (false) immunological reactions. Therefore, the purpose of the study was to examine the immunological (serological) reactivity of tuberculosis patients exposed to gamma radiation in laboratory animals. Radiological, bacteriological, allergic, serological, and pathoanatomical research methods were used in the study. Guinea pigs were consistently irradiated with various doses of gamma rays, infected with Mycobacterium tuberculosis of various types, and, for 90 days, were

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examined by clinical, allergic, pathoanatomical, and serological methods in the complement fixation reaction (CFR) and passive hemagglutination reaction (PHGR) according to Boyden to detect antitubercular complement-binding antibodies and tissue autoantibodies. 45 and 90 days after infection with *M. bovis* and *M. tuberculosis* antitubercular complement-binding antibodies were recorded in serum samples of irradiated and non-irradiated animals in diagnostic titres (1:20-1:80), which indicates the active development of the infectious process. In irradiated and intact guinea pigs infected with *M. avium*, no anti-tuberculosis antibodies were detected in since guinea pigs are not susceptible to infection with the causative agent of avian tuberculosis. In serum samples from uninfected guinea pigs, both irradiated and intact, antitubercular complement-binding antibodies were not detected during the entire follow-up period (90 days). The high content of tissue autoantibodies in blood serum samples of animals irradiated with a dose of 200 R (0.0516 C/kg) is a manifestation of autosensitisation of the body by the breakdown products of its tissues due to radiation damage. The presence of tissue autoantibodies in blood serum samples of irradiated and Mycobacterium-infected animals did not affect serological indicators for the indication of anti-tuberculosis antibodies, which should be considered when conducting diagnostic studies by veterinary medicine laboratories

Keywords: tuberculosis; radiation; tuberculin; gamma radiation; mycobacteria; complement-binding antibodies; tissue antibodies

INTRODUCTION

Tuberculosis has a special place among infectious diseases of farm animals and poultry. The disease of livestock with tuberculosis causes substantial economic damage to animal husbandry and poses a danger to human health. The main method of life-long diagnosis of tuberculosis is clinical and allergic studies, and post-mortem – pathoanatomical and bacteriological. Auxiliary methods for diagnosing tuberculosis include simultaneous allergic, intravenous tuberculin, double intradermal tuberculin tests, ophthalmoprobe in cattle, histological, serological, immunological, and genetic studies. Nowadays, both technogenic accidents at nuclear power enterprises and the use of tactical nuclear weapons during military conflicts are a reality. Therefore, the investigation of radiation effects on biological objects, in particular, on the specificity of diagnostic reactions in the study of infectious diseases, becomes particularly relevant (Candeias, 2017; Cvetnić, 2021).

A number of authors (Akhtar, 2019; Kassich, 2022; Guo, 2021) note the appearance of positive reactions to tuberculin during allergic studies of livestock in the case of sensitisation of the body by atypical mycobacteria and when exposed to various adverse environmental factors, including ionising radiation.

Huang (2019), Wang (2019), Kassich (2019) prove that the reactions of the body to ionising radiation are heterogeneous in microorganisms and animals of different species, and they also differ in individuals of the same species. Researchers report that the biological action of ionising radiation is based on such phenomena as the absorption of radiation energy by the biosubstrate, the formation of active free radicals and ions (conversion of radiation energy into chemical), and the development of primary radiation and chemical reactions after irradiation.

According to Penn-Nicholson (2020), Lumniczky (2021), and Xi (2023) ionisation caused by ionising radiation consists in the formation of active radicals of water and organic substances HO_2+, H+, H_2+, etc. Under the influence of irradiation in the presence of oxygen, atomic hydrogen, hydroxyl, hydroperoxide radical, hydrogen peroxide, and atomic oxygen are formed in water. According to Katalin (2019), Atmakuri (2018), and Gaikwad (2018), the interaction of free radicals with organic and inorganic substances follows the type of redox reactions and constitutes an indirect effect. The mechanism of biological action of ionising radiation is not fully understood. However, it is known that the formed active radicals of water and organic substances actively injure the cells of the irradiated organism, which leads to autoimmune pathology, in particular, to the appearance of tissue autoantigens and anti-tissue autoantibodies (Saeed, 2016).

The first reports of the appearance of anti-tissue autoantibodies in the blood serum of dogs and rabbits after irradiation were made in 1934 by I.P. Mishchenko and M.M. Fomenko (Kassich, 2021). After radiation exposure, autosensitisation of the body occurs due to a violation of the antigenic specificity of proteins. The resulting autoantibodies have cytolytic activity. Sabiiti (2020), Scriba (2021), and Mtafya, (2019) argue that autoimmune reactions in the irradiated body proceed as auto-allergic processes. Some researchers (Basit, 2018; Naei, 2019; Roe, 2020) believe that tissue autoantibodies formed in the irradiated body are involved in increasing its radioresistance, and can also cause the development of non-specific (false) reactions to various antigens and allergens in the irradiated body, which can complicate allergic and serological studies and lead to diagnostic errors during the examination of irradiated animals.

In Ukraine, technogenic accidents at nuclear power enterprises are a reality, and the use of tactical nuclear weapons during a military conflict is also possible.

Therefore, the study of radiation exposure to biological objects, in particular, on the specificity of diagnostic reactions in the study of infectious diseases, becomes particularly relevant. In connection with the above the purpose of the study was the immunological reactivity of laboratory animals under the influence of sublethal doses of gamma radiation was examined.

MATERIALS AND METHODS

Guinea pigs were used in the amount of 200 heads, weighing 300-350 R, selected according to the principle of analogues to examine the regularities of the development of the infectious process in tuberculosis under the influence of ionising radiation. The animals were divided into 5 groups of 40 heads each. Guinea pigs were previously examined (30 days before irradiation) with a tuberculin test to exclude natural tuberculosis. No responders were identified. Four groups of animals were separately irradiated with gamma radiation at doses of 50, 100, 150, and 200 R (0.0129, 0.0258, 0.0387, and 0.0516 C/kg) with a dose rate of 2.65 g/sec on the IGUR gamma emitter (radiation source 137cz).

Irradiated and intact guinea pigs were divided into 2 equal groups of 100 heads each. Animals of the first group were examined one day after irradiation with a simultaneous allergic test with PPD-tuberculin for mammals and AAM. 7 days after irradiation, animals of this group (5-6 irradiated with doses of 50, 100, 150, and 200 R and intact) were infected with mycobacteria of bovine (strain Bovinus 8), human (strain M), and avian (strain Avium 780) types. Mycobacterium cultures were administered subcutaneously to each guinea pig in the groin area of 1 mg of raw bacterial mass suspended in 1 ml of a sterile isotonic NaCl solution. Animals of the second group (uninfected, irradiated and intact) were examined by a simultaneous allergic test 7 days after radiation exposure. 14 days after irradiation, 5 guinea pigs from each irradiated group and intact were infected with *M. bovis, M. tuberculosis* and *M. avium* of the same strains. An electronic photo of mycobacteria of the *M. bovis*production strain is shown in Figure 1.

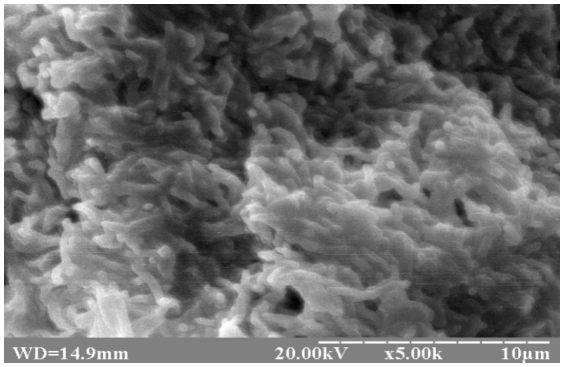

Figure 1. *Mycobacteria of the M. bovis production strain. Stick-shaped conglomerate*
Source: *microphoto by the authors*

14, 45, and 90 days after infection, the animals were examined with a simultaneous allergic test. Blood samples were taken from the heart during the same period for serological and haematological studies. Therewith, from the moment of irradiation to the end of the experiment, clinical observations were made on the state of animal health, the timing of death was considered, and pathoanatomical studies were conducted.

For the indication of antitubercular complement-binding antibodies in serum samples of experimental animals, the complement fixation reaction with the complex tuberculosis antigen UNDIEV was used, which was set up and recorded in accordance with the guidelines for the diagnosis of animal tuberculosis (Guideline for the Prevention and Control of Tuberculosis in Animals, 2009).

Serum samples of animals exposed to various doses of gamma rays were selectively examined (10 samples taken before and after infection) to detect tissue autoantibodies in the passive hemagglutination reaction (PHGR) according to Boyden with tissue antigens manufactured in this study according to the method of Ye.F. Chernushenko (Zazharskyi *et al.,* 2022).

Antigens (water-salt tissue extracts) for PHGR were prepared as follows. Testicular, adrenal, spleen, thymus, and pituitary tissues were thoroughly washed with running water and then with an isotonic NaCl solution. The tissues treated in this way were crushed and homogenised, and filled with a sterile isotonic NaCl solution at a rate of 1:4 for the extraction. The resulting emulsion was kept in a refrigerator at a temperature of 4°C for 18-24 hours, then centrifuged at a 1.5 thousand rpm rate for 20 minutes. The supernatant was used as an antigen. The protein concentration in the antigen was determined using a Lowry spectrophotometer. Information on the protein content of the manufactured antigens is shown in Table 1.

Table 1. *Protein content in tissue antigens*

Protein content (mg/mL) in antigens from:			
thymus	testicle	pituitary	adrenal
0.16	0.41	0.30	0.38

Source: *compiled by the authors*

When working with animals, the provisions of Article 26 of the Law of Ukraine No. 3447-VI of 16.10.2012 "On the Protection of Animals from Cruelty" (2012), "General ethical principles of animal experiments" approved at the first National Congress on Bioethics (Reznikov, 2003), requirements of the "European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes" (European convention, 1986), the "Universal Declaration on Animal Welfare" (Universal Declaration, 2007) were adhered.

RESULTS AND DISCUSSION

The results of examining the serological reactivity of marine animals irradiated and infected with tuberculosis pathogens are given below. Serum samples of experimental animals were tested in the complement fixation reaction with a complex tuberculosis antigen (CTA UNDIEV) developed by Yu.Ya. Kassich (1968) to indicate antitubercular complement-binding antibodies. The antibody titer of 1:20 ratio was considered diagnostic. During the examination of serum samples taken before infection, and 2 weeks after inoculation of irradiated and intact guinea pigs with infectious material, no antitubercular complement-binding antibodies were detected. The results of the serological examination of irradiated and intact animals 1.5 months after infection are shown in Table 2.

Table 2. *Results of the serological examination in the complement fixation reaction (CFR) with complex tuberculosis antigen (CTA) UNDIEV of blood serum samples from irradiated and intact guinea pigs 1.5 months (45 days) after infection*

No. of samples	Irradiation dose (R/C/ kg)	Type of tuberculosis pathogen	Results of RSC with CTA UNDIYEV in titers:			
			1:10	1:20	1:40	1:80
1	2	3	4	5	6	7
1	50/0.0129	*M. bovis*	+	-	-	-
2	50/0.0129	*M. bovis*	++++	++++	-	-
3	50/0.0129	*M. bovis*	++	+	-	-
4	50/0.0129	*M. bovis*	-	-	-	-
5	50/0.0129	*M. tuberculosis*	-	-	-	-
6	50/0.0129	*M. tuberculosis*	++++	++++	++	-
7	50/0.0129	*M. tuberculosis*	++++	++	-	-
8	50/0.0129	*M. tuberculosis*	++++	++++	-	-
9	50/0.0129	*M. avium*	++++	+	-	-
10	50/0.0129	*M. avium*	++++	+	-	-
11	50/0.0129	*M. avium*	++++	++	-	-
12	100/0.0258	*M. bovis*	++++	++++	++	+
13	100/0.0258	*M. bovis*	++++	++	-	-
14	100/0.0258	*M. bovis*	++	++	-	-
15	100/0.0258	*M. bovis*	++++	++++	++++	+
16	100/0.0258	*M. tuberculosis*	++++	++++	++	-
17	100/0.0258	*M. tuberculosis*	++++	++++	-	-
18	100/0.0258	*M. tuberculosis*	++++	++++	++++	+
19	100/0.0258	*M. tuberculosis*	++++	++++	+	-
20	100/0.0258	*M. avium*	++	++	-	-
21	100/0.0258	*M. avium*	-	-	-	-
22	100/0.0258	*M. avium*	-	-	-	-

Table 2, Continued

No. of samples	Irradiation dose (R/C/ kg)	Type of tuberculosis pathogen	Results of RSC with CTA UNDIYEV in titers:			
			1:10	1:20	1:40	1:80
23	150/0.0387	*M. bovis*	++++	++++	++	-
24	150/0.0387	*M. tuberculosis*	++++	++++	++	-
25	150/0.0387	*M. tuberculosis*	-	-	-	-
26	150/0.0387	*M. avium*	-	-	-	-
27	150/0.0387	*M. avium*	++	-	-	-
28	200/0.0516	*M. avium*	-	-	-	-
29	200/0.0516	*M. avium*	-	-	-	-
30	200/0.0516	not infected	-	-	-	-
31	200/0.0516	not infected	-	-	-	-
32	200/0.0516	not infected	-	-	-	-
33	200/0.0516	not infected	-	-	-	-
34	200/0.0516	not infected	-	-	-	-
35	not irradiated	*M. tuberculosis*	-	-	-	-
36	not irradiated	*M. tuberculosis*	++++	++++	++++	+
37	not irradiated	*M. tuberculosis*	++++	++++	++	+
38	not irradiated	*M. avium*	-	-	--	
39	not irradiated	*M. avium*	-	-	-	-
40	not irradiated	*M. avium*	-	-	-	-
41	not irradiated	not infected	-	-	-	-
42	not irradiated	not infected	-	-	-	-

Source: *compiled by the authors*

The materials in Table 2 demonstrate that 45 days after infection with *M. bovis* and *M. tuberculosis,* complement-binding antibodies were recorded in serum samples from irradiated and non-irradiated animals in diagnostic titers (1:20-1:40). Among those infected with *M. avium,* complement-binding antibodies in a titer of 1:10 (below the diagnostic one) were detected in one case in a group of guinea pigs irradiated with a dose of 50 R (0.0129 C/kg).

No complementary antibodies were detected in serum samples of non-infected animals, both irradiated and intact. The results of the serological examination of irradiated and non-irradiated guinea pigs 3 months after infection with mycobacteria are shown in Table 3.

Table 3. *Results of serological examination of blood serum samples from irradiated and intact guinea pigs in rzk with CTA UNDIEV 3 months (90 days) after infection*

No. of samples	Irradiation dose (R/C/ kg)	Type of tuberculosis pathogen	Results of CFR with CTA UNDIEV in the titers:			
			1:10	1:20	1:40	1:80
1	2	3	4	5	6	7
1	50/0.0129	*M. tuberculosis*	++++	++++	+	-
2	50/0.0129	*M. tuberculosis*	-	-	-	-
3	50/0.0129	*M. tuberculosis*	-	-	-	-
4	50/0.0129	*M. avium*	++++	++	-	-
5	50/0.0129	*M. avium*	-	-	-	-
6	50/0.0129	*M. avium*	++	+	-	-
7	100/0.0258	*M. tuberculosis*	++++	++++	++++	-
8	100/0.0258	*M. tuberculosis*	++	++	-	-
9	100/0.0258	*M. tuberculosis*	++++	++	-	-
10	100/0.0258	*M. avium*	+	-	-	-
11	100/0.0258	*M. avium*	-	-	-	-

Table 3, Continued

No. of samples	Irradiation dose (R/C/ kg)	Type of tuberculosis pathogen	Results of CFR with CTA UNDIEV in the titers:			
			1:10	1:20	1:40	1:80
12	100/0.0258	*M. avium*	-	-	-	-
13	150/0.0387	*M. tuberculosis*	++++	++++	++++	++
14	150/0.0387	*M. tuberculosis*	++++	++++	++	-
15	150/0.0387	*M. avium*	-	-	-	-
16	150/0.0387	*M. avium*	-	-	-	-
17	200/0.0516	*M. avium*	-	-	-	-
18	200/0.0516	*M. avium*	-	-	-	-
19	50/0.0129	not infected	-	-	-	-
20	50/0.0129	not infected	-	-	-	-
21	50/0.0129	not infected	-	-	-	-
22	100/0.0258	not infected	-	-	-	-
23	100/0.0258	not infected	-	-	-	-
24	100/0.0258	not infected	-	-	-	-
25	not irradiated	*M. tuberculosis*	++++	++++	_	_
26	not irradiated	*M. tuberculosis*	++++	++++	++++	++++
27	not irradiated	*M. tuberculosis*	++++	++++	++++	++++
28	not irradiated	*M. avium*	-	-	-	-
29	not irradiated	*M. avium*	++	-	-	-
30	not irradiated	*M. avium*	-	-	-	-
31	not irradiated	not infected	-	-	-	-
32	not irradiated	not infected	-	-	-	-
33	not irradiated	not infected	-	-	-	-

Source: *compiled by the authors*

The materials in Table 3 demonstrate that complement-binding antibodies in diagnostic titers (1:20, 1:40, and 1:80) on day 90 of the examination were recorded in irradiated and intact animals infected with *M. tuberculosis*. Therewith, positive results with a titer of 1:80 ratio were determined only in intact animals. In animals, irradiated at doses of 50-200 R (0.0129-0.0516 C/kg), complement-binding antibodies were recorded in titres of 1:10, 1:20, and 1:40. At the time of the study, all guinea pigs infected with the causative agent of bovine tuberculosis (*M. bovis)* died with a picture of generalised tuberculosis with a substantial increase in the spleen and liver, tubercles and foci of caseous necrosis in parenchymal organs (Fig. 2).

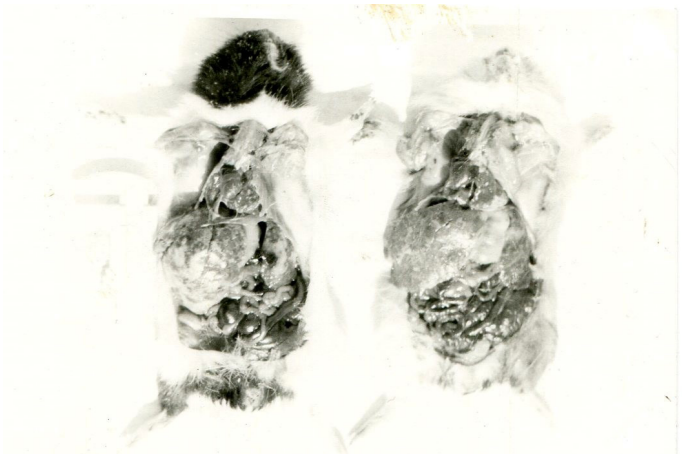

Figure 2. *Generalised tuberculosis of guinea pigs that died 25 days after being infected with M. bovis*
Note: *On the left – irradiated with a dose of 150 R (0.0387 C/kg). On the right – not irradiated*
Source: *photographed by the authors*

Antitubercular complement-binding antibodies were not identified in diagnostic titers exposed to gamma radiation and intact, Mycobacterium-infected guinea pigs with tuberculosis of avian type, which is natural, since guinea pigs are not susceptible to infection with *M. avium*. No complementary antibodies were detected in serum samples from uninfected guinea pigs, both irradiated and intact. Blood serum samples from animals irradiated with different doses of gamma radiation were selectively examined (10 sera selected before and after irradiation) in the passive hemagglutination reaction according to Boyden to identify tissue autoantibodies formed in the irradiated body in response to radiation damage to their tissues, which simultaneously become autoantigens and cause the development of immunological auto-allergic reactions (Zazharskyii *et al.,* 2022).

Table 4. *Results of indication of tissue autoantibodies in serum samples of infected, irradiated and intact guinea pigs 45 days after infection*

No. of samples	Irradiation dose (R/C/kg)	Type of tuberculosis pathogen	Results of PHGR (maximum titer of autoantibodies) with tissue antigens from:			
			thymus	testicles	pituitary	adrenal
1	2	3	4	5	6	7
1	50/0.0129	not infected	-	-	-	-
2	50/0.0129	not infected	-	-	-	-
3	50/0.0129	not infected	-	-	-	-
4	50/0.0129	not infected	-	1:2	-	-
5	50/0.0129	not infected	1:2	1:16	1:16	1:16
6	50/0.0129	*M. bovis*	-	-	-	-
7	50/0.0129	*M. tuberculosis*	-	-	1:2	-
8	50/0.0129	*M. avium*	-	1:2	-	-
9	50/0.0129	*M. bovis*	-	-	-	-
10	50/0.0129	*M. tuberculosis*	1:2	1:4	1:4	1:4
11	100/0.0258	not infected	-	-	-	-
12	100/0.0258	not infected	-	-	-	-
13	100/0.0258	not infected	-	-	-	-
14	100/0.0258	not infected	-	-	-	-
15	100/0.0258	not infected	-	-	-	-
16	100/0.0258	*M. bovis*	-	-	-	-
17	100/0.0258	*M. bovis*	-	-	-	-
18	100/0.0258	*M. tuberculosis*	-	-	-	-
19	100/0.0258	*M. tuberculosis*	-	-	-	-
20	100/0.0258	*M. avium*	-	-	-	-
21	150/0.0387	not infected	-	-	-	-
22	150/0.0387	not infected	-	-	-	-
23	150/0.03871	not infected	-	-	1:2	-
24	150/0.0387	not infected	-	-	-	-
25	150/0.0387	not infected	-	-	-	-
26	150/0.0387	*M. bovis*	-	-	-	-
27	150/0.0387	*M. bovis*	-	-	-	-
28	150/0.0387	*M. tuberculosis*	-	1:2	-	-
29	150/0.0387	*M. tuberculosis*	-	1:2	-	-
30	150/0.0387	*M. avium*	-	1:2	-	-
31	200/0.0516	not infected	1:128	1:128	1:4096	1:4096

Table 4, Continued

32	200/0.0516	not infected	1:512	1:512	1:4096	1:4096
33	200/0.0516	not infected	1:128	1:128	1:4096	1:4096
34	200/0.0516	not infected	1:512	1:512	1:4096	1:4096
35	200/0.0516	*M. bovis*	1:128	1:128	1:4096	1:4096
36	200/0.0516	*M. bovis*	1:128	1:128	1:4096	1:4096
37	200/0.0516	*M. tuberculosis*	1:512	1:1024	1:4096	1:4096
38	200/0.0516	*M. tuberculosis*	1:128	1:128	1:4096	1:4096
39	200/0.0516	*M. tuberculosis*	1:512	1:1024	1:4096	1:4096
40	200/0.0516	*M. tuberculosis*	1:512	1:1024	1:4096	1:4096
41	not irradiated	not infected	-	-	-	-
42	not irradiated	not infected	-	-	-	-
43	not irradiated	not infected	-	-	-	-
44	not irradiated	*M. bovis*	-	-	-	-
45	not irradiated	*M. tuberculosis*	-	-	-	-
46	not irradiated	*M.tuberculosis*	-	-	-	-
47	not irradiated	*M. avium*	-	-	-	-

Source: *compiled by the authors*

From the data shown in Table 4, it follows that tissue autoantibodies in high titers (1:128-1:4096) are detected in the blood serum of animals exposed to the gamma radiation at a dose of 200 R (0.0516 C/kg). In one case, autoantibodies in diagnostic titers of 1:16 were detected in a group of guinea pigs who were not infected with tuberculosis at a dose of 50 R (0.0129 C/kg).

The results of examining the immunological reactivity of animals irradiated and infected with tuberculosis pathogens are given in previous studies (Allen, 2018; Chaisson, 2019). It was determined that 14-60 days after infection with tuberculosis pathogens *M. bovis, M. tuberculosis,* and *M. avium* 90-100% of laboratory animals developed allergic reactions to PPD-tuberculin in mammals and poultry, mainly to a homologous allergen. Allergic reactivity persisted until 90 days into the study. After exposure to sublethal doses of gamma rays, guinea pigs developed non-specific reactions to tuberculin, malein, and brucelin. Non-specific reactions to mycobacterial allergens at a dose load of 200 R were observed in 16.6%; 150 R – 5.3% in the group, and after 27 days in irradiated doses of 50 R and 100 R in 25% and 33% of the examined animals. Reactions were manifested in the form of infiltrates at the site of allergen administration with necrosis in the centre and developed over time in the same time frame as specific tuberculin reactions. Isolated reactions to brucelin and malein occurred in animals infected with the causative agent of tuberculosis 60 days after irradiation at doses of 50 R, 100 R, and 150 R. The manifestation of non-specific allergies in irradiated animals depended on the radiation dose rate and radiosensitivity of the animals.

Few researchers have investigated the effect of ionising radiation on antibody formation after the infection of animals with the causative agent of tuberculosis. Thus, Oyarzabal (2019) showed a slight increase in hemagglutinin titers in guinea pigs infected with bovine Mycobacterium tuberculosis, irradiated with gamma radiation at doses of 100-150 R and intact in the hemagglutination reaction (HGR) with alttuberculin. Experiments were conducted on a small number of animals, so these results, according to the authors, can only be indicative.

(Burel, 2019; Belay, 2021; Donovan, 2020) observed the appearance of autoantibodies 15-30 days after irradiation when irradiating animals with tuberculosis. Data on the indication of antitubercular complement-binding antibodies in the blood of irradiated animals infected with the causative agent of tuberculosis was not identified in the available literature.

Some researchers (Torres, 2019; Gupta, 2020) believe that tissue autoantibodies formed in the irradiated body can cause the development of non-specific (false) reactions to various antigens and allergens, which makes it difficult to conduct allergic and serological studies and can lead to diagnostic errors during the examination of irradiated animals. In the experiments of this study, tissue autoantibodies to antigens from the thymus, testicles, adrenal, and pituitary glands in high titers (1:128-1:4096) were detected only in the blood serum of animals exposed to gamma radiation at a dose of 200 R (0.0516 C/kg). The high content of tissue autoantibodies in blood serum samples irradiated with a dose of 200 R (0.0516 C/kg) of animals is a manifestation of autosensitisation of the body by the products of decay of their own tissues due to radiation damage and the cause of the development of non-specific reactions to bacterial allergens, which were detected during

previous studies and described in literature sources. The results obtained in this paper coincide with the data of other researchers presented in the literature sources (Bhattacharya, 2016; Broderick, 2021).

Notably, the presence of tissue autoantibodies in blood serum samples of irradiated and Mycobacterium-infected animals does not affect serological parameters for indicating antitubercular complement-binding antibodies in CFR. Cross-reactivity and false reactions of tissue antibodies of the irradiated organism with complex tuberculosis antigen (CTA UNDIEV) were not observed. Evidently, tissue autoantibodies formed in the irradiated body do not have active centres complementary (affinity) to mycobacterial determinants present in CTA.

CONCLUSIONS

The immunological reactivity of animals with tuberculosis under the influence of ionising radiation was determined. In those infected with Mycobacterium bovine (*M. bovis*) and human (*M. tuberculosis*) types of tuberculosis, irradiated and intact guinea pigs with sublethal doses of gamma radiation develop serological reactions 45 and 90 days after infection, and antitubercular complement-binding antibodies are detected in diagnostic titers.

No antitubercular complement-binding antibodies were detected in diagnostic titers in guinea pigs exposed to gamma radiation and intact, infected with Mycobacterium tuberculosis of avian type. No complementary antibodies were detected in serum samples of non-infected animals, both irradiated and intact.

On day 90 of the study, complement-binding antibodies in diagnostic titers were recorded in irradiated and intact animals infected with *M. tuberculosis*. Therewith, positive results with a titer of 1:80 ratio were determined only in intact animals. In guinea pigs, irradiated at doses of 50-200 R (0.0129-0.0516 C/kg) infected with *M. tuberculosis*, complement-binding antibodies were recorded at titers of 1:10, 1:20, and 1:40.

In the blood serum of animals exposed to gamma radiation at a dose of 200 R (0.0516 C/kg), tissue autoantibodies in high titers are detected (1:128-1:4096). The presence of tissue autoantibodies in blood serum samples of irradiated and Mycobacterium-infected animals does not affect serological parameters for indicating antitubercular complement-binding antibodies in CFR. Cross-reactivity and false reactions of tissue antibodies of the irradiated organism with complex tuberculosis antigen (CTA UNDIEV) were not observed.

The prospect of further research is to examine the immunological reactivity of animals irradiated and infected with tuberculosis using special immunological methods: the reaction of delayed migration of lymphocytes, the reaction of blasttransformation of lymphocytes and the reaction of blood mononuclears, and molecular genetic methods.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Імунологічна реактивність хворих на туберкульоз тварин в умовах впливу іонізуючої радіації

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Анотація. Ефективна боротьба з туберкульозом тварин можлива лише при всебічному вивченні біології збудника, епізоотології, патогенезу, методів профілактики, економічних і екологічних факторів, які впливають на перебіг хвороби. Відомо, що радіаційне опромінення призводить до аутосенсибілізації організму продуктами розпаду власних тканин і розвитку неспецифічних (хибних) імунологічних реакцій. Тому метою дослідження було провести роботу з вивчення імунологічної (серологічної) реактивності хворих на туберкульоз опромінених гамма-радіацією лабораторних тварин. В роботі використовували радіологічні, бактеріологічні, алергічні, серологічні, патологоанатомічні методи досліджень. Мурчаків послідовно опромінювали різними дозами гамма-променів, заражали мікобактеріями туберкульозу різних видів і, впродовж 90 діб, досліджували клінічними, алергічними, патологоанатомічними та серологічними методами в реакції зв'язування комплементу (РЗК) та реакції пасивної гемаглютинації (РПГА) за Бойденом для виявлення протитуберкульозних комплементзв'язуючих антитіл та тканинних аутоантитіл. Через 45 та 90 діб після зараження *M. bovis* та *M. tuberculosis* в пробах сироватки крові опромінених та не опромінених тварин реєстрували протитуберкульозні комплементзв'язуючі антитіла в діагностичних титрах (1:20-1:80), що свідчить про активний розвиток інфекційного процесу. У опромінених та інтактних, інфікованих *M. avium* мурчаків протитуберкульозних антитіл не було виявлено, оскільки морські свинки не сприйнятливі до зараження збудником туберкульозу пташиного виду. У пробах сироваток крові від незаражених мурчаків, як опромінених, так і інтактних, протитуберкульозні комплементзв'язуючі антитіла не виявляли впродовж всього терміну спостереження (90 діб). Високий вміст тканинних аутоантитіл в пробах сироватки крові опромінених дозою 200 Р (0,0516 Кл/кг) тварин є проявом аутосенсибілізації організму продуктами розпаду власних тканин внаслідок радіаційного ураження. Наявність в пробах сироватки крові опромінених та заражених мікобактеріями тварин тканинних аутоантитіл не впливало на серологічні показники з індикації протитуберкульозних антитіл, що треба враховувати під час проведення діагностичних досліджень лабораторіями ветеринарної медицини

Ключові слова: туберкульоз; радіація; туберкулін; гамма-опромінення; мікобактерії; комплементзв'язуючі антитіла; тканинні антитіла