MORPHOLOGICAL STUDY OF THE HEARTS OF RATS CARRIED ON BOARD BIOSATELLITES

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The hearts of rats carried on board the biosatellites "Kosmos-605" and "Kosmos-782" were studied histologically and histochemically. A long space flight (up to 22 days) did not cause any significant structural or metabolic changes to develop in the heart. The absolute weight of the heart also was unchanged. A transient increase in phosphorylase activity in the myocardium of the rats 10-11 h after the end of the flight was due to stress resulting from exposure to the combination of extremal factors accompanying landing of the satellite.

KEY WORDS: *myocardium; space flight.*

The results of physiological investigations show that during long space flights the heart muscle goes out of training, and this is reflected in a decrease in the orthostatic resistance and working capacity of astronauts [1, 3, 4, 11-14]. Whether the development of this state of the heart muscle is accompanied by structural and metabolic changes in the myocardium is not yet clear. After a relatively short flight on satellite ship No. 2, transient cloudy swelling and fatty degeneration were observed in the myocardium of mice [8], whereas during the investigation of turtles flying on the "Zond-5" satellite no pathological changes were found in the heart [2]. As regards the results of autopsy and microscopic investigation of the heart of the monkey "Bonni" which flew on the satellite "Biosatellite-3," most of the pathological changes found were in all probability the result of resuscitation measures undertaken to save the monkey's life [10].

This paper gives the results of histological and histochemical investigations of the hearts of rats carried on board the artificial earth satellites (AES) "Kosmos-605" and "Kosmos-782."

EXPERIMENTAL METHOD

The test material consisted of the hearts of seven rats carried on board the AES "Kosmos-782" for 19.5 days and 15 rats spending 22 days on board the AES "Kosomos-605." The animals from the AES "Kosmos-782" were killed 10-11 h (four rats) and 25 days (three rats) after the end of the flight, and the animals from the AES "Kosmos-605" 2 days (eight rats) and 27 days (seven rats) after landing of the AES. As the control to both experiments hearts were studied from 7 and 15 rats, respectively tively, from a synchronous ground experiment in which all the factors of space flight except weightlessness were simulated, and the hearts of 7 and 15 intact rats kept in the animal house throughout the experiment. Immediately after sacrifice, the animal's heart was cut with a safety razor blade into two parts perpendicularly to the long axis of the organ. The part including the atria, the valve system, and part of the ventricles was fixed with neutral formalin, embedded in paraffin wax, and used for histological investigation. Sections cut in a cryostat from the other part of the heart (ventricles) were used to determine the activity of succinate, malate, isocitrate, β-hydroxybutyrate, α-glycerophosphate, and $NADH_2$ dehydrogenases, phosphorylases A and B, and the lipid content.

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EXPERIMENTAL RESULTS

The absolute weight of the hearts of the rats carried on the AES "Kosmos-605" showed no change compared with animals from the synchronous ground experiments or the intact rats, whereas the relative weight of the hearts of the rats of the flight group killed 2 days after the end of the flight was increased, on account of the slower gain in weight of the animals of the experimental group. On the 27th day after landing, when the weight of the animals of the flight group was the same as that of the control rats, the relative weight of the heart also was back to normal. Consequently, long space flights do not cause atrophy of the myocardium and the decrease in size of the heart shadow on the roentgenograms observed on examination of astronauts after flight is due to the smaller volume of blood in it [13].

On histological examination of the hearts of rats killed 10-11 h and 2 days and also of those killed 25 and 27 days after the end of the space flights no changes were found in either the myocardium or the valve system or the blood vessels of the heart compared with the animals of the control groups. In some places in both the experimental and the control rats, groups of fibers and single fibers with a homogeneous cytoplasm, staining poorly with eosin, were found; after staining by Heidenhain's azan method and with iron hematoxylin, these areas became crimson and black, respectively. These changes in the structure and staining properties of some of the muscle fibers, in the modern view [5-7, 9], are due to excessive contraction of the fibers at the time when the animals were killed and are described in the literature as "contracture degeneration." Areas with sharply dilated and congested capillaries and veins, sometimes with small hemorrhages, were observed in the myocardium of the rats of the experimental and control groups; in some places moderate diffuse proliferation of the connective tissue cells of the stroma of the myocardium were observed and, in a few cases, newly formed cartilage could be seen at the base of the valves. The two last types of changes are frequently seen in the myocardium of rats, and their frequency rises with an increase in the animals' age; as regards focal disturbances of the microcirculation, changes of this type, like "contracture degeneration" of the muscle fibers, most probably arose at the time the animals were killed.

Histochemical investigation of the myocardium of the rats killed 10-11 h after the end of the flight showed an increase in phosphorylase A and B activity, which returned to normal after 25 days. In rats decapitated 2 days after the end of the flight, no increase in the phosphorylase A or B activity was observed in the myocardium. Changes in the activity of the other enzymes investigated or in the concentration of free lipids in the myocardium of rats killed 10-11 h, or 2, 25, and 27 days after landing of the biosatellites were not found. The increase in phosphorylase activity in the myocardium of the rats 10-11 h after the end of the flight could be attributed to an increase in its adrenalin concentration, for adrenalin is known to activate phosphorylase in the rat myocardium [15]. The rise in the adrenalin level in the myocardium, in turn, was in all probability the result of acute stress, as shown by the massive destruction of lymphocytes in the thymus, and which, to judge from the time of its occurrence, developed at the moment of landing of the satellite.

The results of these investigations thus indicate that space flight for 19.5-22 days causes no significant structural or metabolic changes in the heart detectable with the aid of the light microscope. However, it must be emphasized that the results of these investigations cannot be extrapolated completely to man, for in rats, unlike in man, there is no redistribution of the blood in the body during space flight.

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RELATIONS BETWEEN MUSUCLAR AND CONNECTIVE TISSUE COMPONENTS OF THE RAT HEART IN EXPERIMENTAL MYOCARDIAL INFARCTION

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After the first day of experimental myocardial infarction in rats the volume and mean number of connective tissue stromal cells are increased in the "intact" zones of the left ventricle; on the second day of the experiment these indices reach their maximum, and by the 20th day they are equal to the values for the myocardium of control animals. On the third day of the experiment the number of muscle nuclei per standard area of cross section is increased, evidently as the result of amitotic division of the myocyte nuclei, for the number of paired nuclei is increased at the same time.

KEY WORDS: *myocardial infarction; volume of stroma; paired nuclei.*

In the course of histogenesis the muscle cells of the mammalian myocardium lose their ability to divide by mitosis [3, 5]. The subsequent increase in size of the heart, whether the myocardium be normal or injured, in the adult individual is due mainly to hypertrophy of the myocytes and takes place through hyperplasia and hypertrophy of the ultrastructures of the muscle cells [6-8]. At the same time the volume of the nuclei of the muscle cells of the human heart increases, and a high degree of ploidy is reached [9, 13]. A significant increase in the number of muscle nuclei in the hypertrophied myocardium of man and experimental animals also has been discovered [11, 12, 14]. The number of amitotically dividing myocyte nuclei is increased after wounds and infarcts of the myocardium, especially around the zone of damage [2, 4, 10]. In the investigation described below changes in the relations between the muscular and connective tissue component of "intact" zones of the rat heart and the number of paired myocyte nuclei at different stages of myocardial infarction were studied.

EXPERIMENTAL METHOD

Experiments were carried out on 24 noninbred male albino rats weighing 90-100 g. In 18 rats a myocardial infarct was produced by suture and ligation of the rat coronary artery. The animals were killed with ether 1, 2, 3, 5, 7, 15, 30, and 90 days after the beginning of

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