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CHARACTERISTIC MACRO- AND MICROSCOPIC CHANGES OF MYOCARDIA UNDER THE INFLUENCE OF MICROWAVE ELECTROMAGNETIC RADIATION UNDER CONDITIONS OF HYPOTHYROID STATE

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An urgent problem in Ukraine is the development of measures that ensure the adaptation of the cardiovascular system in conditions of hypothyroidism. Nervous, endocrine and cardiovascular systems are the first to react to electromagnetic radiation . It is known that microwave radiation has an effect on heart cells and, therefore, on its functioning. The purpose of the study is to study the morphological changes of the myocardium after exposure of microwave electromagnetic radiation with different duration of exposure both independently and after thyroidectomy. The object of the study was the hearts of sexually mature laboratory rats. In the course of the experiment, the myocardium of rats with a hypothyroid state was studied under the influence of microwave electromagnetic radiation of various durations. After exposure of electromagnetic radiation for different periods of exposure – 45 and 120 minutes – morphometric and histological studies were used to establish structural features and changes in the heart, which made it possible to quantitatively assess the processes of morphological transformations at the organ and tissue levels. Changes in the myocardium of experimental animals under conditions of a hypothyroid state after exposure of microwave electromagnetic radiation with an exposure time of 45 and 120 minutes differed in different experimental groups. A 45-minute exposure period of microwave electromagnetic radiation led to minor changes in the myocardium of rats, and had a positive effect on the morphology and reparative properties of the heart wall of experimental animals. Changes of a different nature were observed after exposure of microwave electromagnetic radiation with an exposure period of 120 minutes: an increase in degenerative and destructive processes in the myocardium was noted, degradation processes were significantly enhanced and prevailed over compensatory-adaptive processes.

Key words: *heart, myocardium, thyroidectomy, hypothyroid state, microwave electromagnetic radiation.*

Connection of the publication with planned research works. Dissertation work of the Doctor of Philosophy on the topic: «Morphological changes of the myocardium under the action of electromagnetic radiation in normal and after thyroidectomy (anatomical-experimental study)». The research was carried out within the framework of the scientific topic of the Department of Clinical Anatomy, Anatomy and Operative Surgery of the Dnipro State Medical University «Morphofunctional state of organs and tissues of experimental animals and humans in ontogenesis in normal and under the influence of external and internal factors», state registration number 0117U003181.

Introduction. Corrective measures aimed at protection and adaptation of the cardiovascular system in conditions of a hypothyroid state are important and unresolved questions in modern Ukraine [1, 2, 3]. The problems of the consequences of hypothyroidism, which occurs after thyroidectomy, on the morphogenesis of the heart under the influence of electromagnetic radiation are also relevant, taking into account the fact that the nervous, endocrine and cardiovascular systems are the first to react to the action of electromagnetic radiation [4]. It is known that it is microwave radiation that affects the cells of the heart and, therefore, its functioning [5]. According to the literature, toxic and therapeutic doses of some substances, including heavy metals, have been determined experimentally, but the question of the consequences of hypothyroidism, which occurs after thyroidectomy, on the morphogenesis of the heart under conditions of exposure to electromagnetic radiation remains unresolved [6, 7, 8]. Such characteristics of electromagnetic radiation as radiation frequency, wavelength, and exposure time, which have a significant impact on heart morphogenesis, remain important issues [9].

Hypofunction of the thyroid gland as a result of thyroidectomy leads to the development of hypertrophy of the myocardium of the left ventricle and an increase in its mass, which can disrupt the processes of diastolic relaxation, and the imbalance of thyroid hormones causes a violation of the contractile function of the myocardium [10].

With the help of induced experimental models, it becomes possible to analyze the morphological changes of the heart after thyroidectomy under the influence of electromagnetic radiation [11, 12]. Modeling the pathological condition, identifying the terms, causes and mechanism of the formation of disturbances in the morphogenesis of the heart wall and its structural elements will help determine possible corrective measures under the influence of electromagnetic radiation [13]. Thus, an important and relevant direction of morphological experimental research is the detection of the spectrum of changes in the structural components of the heart wall under conditions of hypothyroidism, prediction of cardiovascular pathologies and possible compensatory or decompensatory effects of electromagnetic radiation with different exposure periods.

The aim of the study. To establish macro- and microscopic changes in the myocardium of the heart of experimental animals under the influence of electromagnetic radiation under the conditions of modulation of hypothyroidism. To investigate the morphological changes of the myocardium of rats under

the conditions of a hypothyroid state at different times of exposure to electromagnetic radiation.

Object and methods of research. The object of the study was the hearts of sexually mature laboratory rats weighing 180-200 g, aged 4-6 months. The study involved 126 animals divided into control and five experimental groups. This section of the experiment concerned the observation of the following experimental groups of rats: control; after thyroidectomy; after thyroidectomy and after exposure to microwave radiation for 45 minutes; after thyroidectomy and after exposure to microwave radiation for 120 min.

The method of modeling hypothyroidism was carried out according to the patented useful model of 2007, No. 54; (19) UA(11)27821(13)U.

The influence of electromagnetic radiation was studied after irradiation with a high-frequency signal generator – G4 – 83 (7.5 – 10.5 GHz) with a frequency of 10 GHz, with a wavelength of 3 cm, exposure of 45 and 120 minutes, daily for 10 days on the whole body with a pyramidal horn – type P 6 – 23A with a power flux density of 1.1*10-3 W/m². This experiment was conducted at the Department of Applied Radiophysics, Electronics nd Nanomaterials of the Oles Honchar Dnipro National University, in accordance with the concluded agreement on scientific and creative cooperation.

Animals were removed from the experiment on

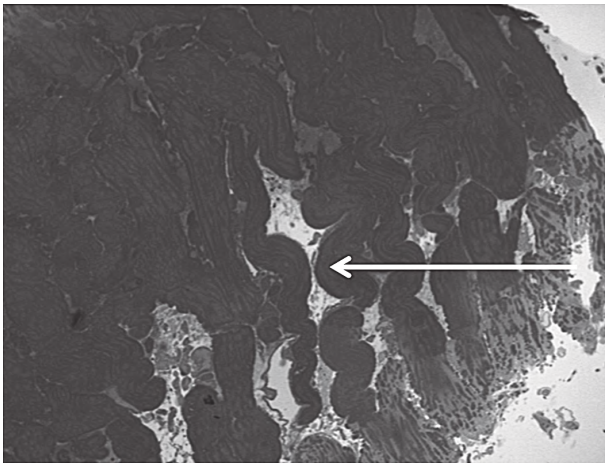

Figure 1 – Myocardium of the heart wall after thyroidectomy. Staining: water blue. Inc.: x 40. The arrow indicates muscle fibers.

the 11th day in compliance with the requirements of humane treatment of experimental animals.

Dissection was used after postmortem thoracotomy, study of cardiac syntopy and isolation of rat hearts from the chest cavity. Measurements and weight indicators of rat hearts were taken.

In the process of work, the following were used: experimental modeling, morphometric and histological research methods [14], statistical processing of research materials using biostatistics methods implemented in the program STATISTICA v.6.1 (Statsoft Inc., USA) (licensed № AGAR909E415822FA) and program Microsoft Excel (Microsoft Office 2016 Professional Plus, Open License 67528927).

Experimental studies were carried out in compliance with the requirements of humane treatment of experimental animals, regulated by the Law of Ukraine «On the Protection of Animals from Cruelty» (No. 3447-IV dated 21.02.2006) and the European Convention on the Protection of Vertebrate Animals Used for Research and Other scientific goals (Strasbourg, March 18, 1986).

Research results and their discussion. Studying the hearts of rats, we determined changes at the macro level in weight indicators of rat hearts. In rats of the control group, after removal of the heart from the chest cavity, the weight of the heart was on average equal to: 0.60 ± 0.028 g. The relative weight of the heart in the control and experimental groups after exposure to electromagnetic radiation with different duration of exposure was as follows: after thyroidectomy – 0.35%; after exposure to electromagnetic radiation for 45 minutes in conditions after thyroidectomy – 0.35%; and after thyroidectomy and an exposure time of 120 minutes – 0.44%.

Therefore, analyzing the morphometric parameters in normal conditions and after exposure of microwave electromagnetic radiation with different duration of exposure, it can be concluded that after exposure of microwave electromagnetic radiation in conditions of a hypothyroid state with an exposure period of 45 minutes, there was a slight fluctuation of the indicators, which practically did not differ from the indicators control group. However, after exposure of microwave electromagnetic radiation in conditions of a hypothyroid state with an exposure period of 120 minutes, these indicators changed more clearly compared to the control group.

Analysis of changes at the level of the organ, that is, the heart, showed that the weight of the heart after thyroidectomy and exposure to electromagnetic radiation with an exposure period of 120 minutes increases by 1.2 times and is 0.85 ± 0.011 g on average. Such changes were interpreted as a destructive effect of this term of microwave electromagnetic radiation, which led to a more pronounced defibrillation of muscle fibers in the myocardium of rats, and, as a result, swelling of interstitial spaces and disruption of blood supply at the microcirculatory level.

During a morphological study under the conditions of simulating hypothyroidism after thyroidectomy at the microscopic level, destructive changes are observed in the myocardium – signs with elements of myocardial dystrophy, with foci of myocardial dystrophy, up to microinfarcts with perifocal inflammation, as well as degeneration processes (appearance of contractile bands) of muscle fibers and the appearance diffuse necrosis of cardiomyocytes. At the site of irreversible damage, the formation of connective tissue scars and interstitial fibrosis is possible **(fig. 1)**.

After thyroidectomy and exposure of microwave electromagnetic radiation with exposure for 45 minutes, compensatory remodeling of the unchanged structural components of the myocardium of the heart wall and hypertrophy of cardiomyocytes were observed, which demonstrates the reparative and regenerative effect of microwave electromagnetic radiation on the myocardium after 45 minutes of exposure **(fig. 2)**.

After thyroidectomy and exposure of microwave electromagnetic radiation for 120 minutes, an increase in degenerative and destructive processes in the myocardium of the heart wall was observed, which indicates the suppressive effect of microwave radiation on cardiomyocytes **(fig. 3)**.

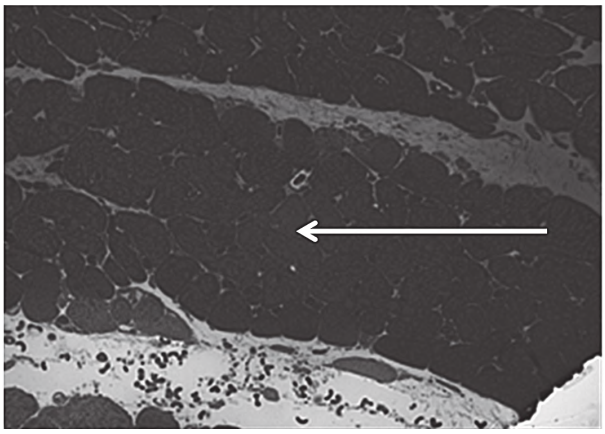

Figure 2 – Myocardium of the heart wall after thyroidectomy and microwave electromagnetic radiation with an exposure of 45 minutes. Staining: water blue. Inc.: x 40. The arrow indicates muscle fibers.

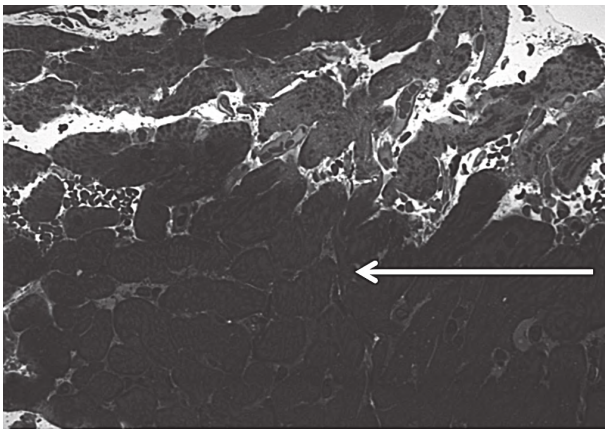

Figure 3 – Myocardium of the heart wall after thyroidectomy and microwave electromagnetic radiation with an exposure of 120 minutes. Staining: water blue. Inc.: x 40. The arrow indicates muscle fibers.

Conclusions. Under the conditions of simulation of hypothyroidism after thyroidectomy, destructive changes and processes of degeneration of muscle fibers were observed in the myocardium, but after exposure of microwave electromagnetic radiation on animals in a hypothyroid state for 45 minutes, regenerative compensatory restructuring of the structural components of the myocardium of the heart wall occurs; after thyroidectomy and exposure of microwave electromagnetic radiation for 120 minutes, an increase in degenerative and destructive processes in the myocardium of the heart wall is observed, which indicates the suppressive effect of microwave electromagnetic radiation on cardiomyocytes during exposure for 120 minutes.

Prospects for further research. It is planned to investigate ultramicroscopic changes in the myocardium of the heart wall under conditions of simulation of hypothyroidism after thyroidectomy and exposure to microwave electromagnetic radiation using the electron microscopy method.

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ХАРАКТЕРНІ МАКРО- ТА МІКРОСКОПІЧНІ ЗМІНИ МІОКАРДА ПІД ВПЛИВОМ НАДВИСОКОЧАСТОТНОГО ЕЛЕКТРОМАГНІТНОГО ВИПРОМІНЮВАННЯ ЗА УМОВ ГІПОТИРЕОЇДНОГО СТАНУ

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Резюме. Невирішені питання стосовно впливу електромагнітного випромінювання на міокард в умовах гіпотиреоїдного стану потребують поглибленого вивчення цієї актуальної та важливої сучасної проблеми. Метою дослідження є встановлення макро- та мікроскопічних змін у міокарді серця експериментальних тварин за умов моделювання гіпотиреозу під впливом НВЧ електромагнітного випромінювання.

Об'єктом дослідження стали серця 126 лабораторних статевозрілих щурів, масою 180 – 200 г віком 4-6 місяців, розподілені на контрольну та п'ять експериментальних груп. Даний розділ експерименту стосу-

вався спостереження за наступними експериментальними групами щурів: контрольною; після тиреоїдектомії; після тиреоїдектомії та після дії НВЧ-випромінювання 45 хв.; після тиреоїдектомії та після дії НВЧ-випромінювання 120 хв. Експериментальні тварини опромінені НВЧ електромагнітним випромінюванням з частотою 10 ГГц, з довжиною хвилі 3 см при різних термінах експозиції – 45 та 120 хвилин – щоденно протягом 10 діб.

Досліджуючи серця щурів, ми визначили зміни на макрорівні у вагових показниках сердець щурів. Аналіз змін на рівні органу, тобто серця, показав, що найбільші зміни щодо маси серця спостерігалися у стані експериментально отриманого гіпотиреозу та впливі надвисокочастотного електромагнітного випромінювання з терміном експозиції 120 хвилин. Таке збільшення маси серця у групі щурів даної групи було оцінено нами як деструктивний вплив, що пов'язаний з більш вираженим розволокненням м'язових волокон у міокарді стінки серця шлуночків щурів, та, як наслідок, набряком інтерстиціальних просторів та порушенням кровопостачання на мікроциркуляторному рівні.

При морфологічному дослідженні за умов моделювання гіпотиреозу після тиреоїдектомії на мікроскопічному рівні у міокарді спостерігалися деструктивні зміни, процеси дегенерації м'язових волокон. Після тиреоїдектомії та впливу НВЧ випромінювання з експозицією 45 хвилин ми спостерігали компенсаторну перебудову незмінних структурних компонентів міокарду стінки серця та гіпертрофію кардіоміоцитів, що є свідоцтвом адаптивної, репаративно-регенераторної дії на міокард НВЧ електромагнітного випромінювання терміном 45 хв. У групі щурів після тиреоїдектомії та впливу НВЧ електромагнітного випромінювання з експозицією 120 хвилин спостерігали посилення дегенеративно-деструктивних процесів у міокарді з набряком інтерстиціальних просторів, що свідчить про пригнічуючу та деструктивну дію НВЧ електромагнітного випромінювання даного терміну на кардіоміоцити.

Ключові слова: серце, міокард, тиреоїдектомія, гіпотиреоїдний стан, НВЧ – електромагнітне випромінювання.

CHARACTERISTIC MACRO- AND MICROSCOPIC CHANGES OF MYOCARDIA UNDER THE INFLUENCE OF MICROWAVE ELECTROMAGNETIC RADIATION UNDER CONDITIONS OF HYPOTHYROID STATE

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Abstract. Unsolved questions regarding the impact of electromagnetic radiation on the myocardium in conditions of a hypothyroid state require an in-depth study of this current and important modern problem. The purpose of the study is to establish macro- and microscopic changes in the myocardium of the heart of experimental animals under the conditions of modeling hypothyroidism under the influence of microwave electromagnetic radiation.

The object of the study were the hearts of 126 laboratory sexually mature rats weighing 180-200 g, aged 4-6 months, divided into control and five experimental groups. This section of the experiment concerned the observation of the following experimental groups of rats: control; after thyroidectomy; after thyroidectomy and after exposure to microwave radiation for 45 minutes; after thyroidectomy and after exposure to microwave radiation for 120 min. Experimental animals were irradiated with microwave electromagnetic radiation with a frequency of 10 GHz, with a wavelength of 3 cm at different exposure times – 45 and 120 minutes – daily for 10 days.

Studying the hearts of rats, we determined changes at the macro level in weight indicators of rat hearts. Analysis of changes at the level of the organ, i.e. the heart, showed that the greatest changes in heart weight were observed in the state of experimentally obtained hypothyroidism and the influence of ultra-high-frequency electromagnetic radiation with an exposure period of 120 minutes. Such an increase in the weight of the heart in the group of rats of this group was assessed by us as a destructive effect, which is associated with a more pronounced defibration of muscle fibers in the myocardium of the heart wall of the ventricles of rats, and, as a result, swelling of the interstitial spaces and disruption of blood supply at the microcirculatory level.

During the morphological study under the conditions of modeling hypothyroidism after thyroidectomy at the microscopic level, destructive changes and degeneration processes of muscle fibers were observed in the myocardium. After thyroidectomy and exposure of microwave electromagnetic radiation for 45 minutes, we observed compensatory remodeling of unchanged structural components of the myocardium of the heart wall and hypertrophy of cardiomyocytes, which is evidence of the adaptive, reparative-regenerative effect of microwave electromagnetic radiation on the myocardium for 45 minutes. In a group of rats after thyroidectomy and exposure to microwave radiation with exposure for 120 minutes, an increase in degenerative-destructive processes in the myocardium with swelling of interstitial spaces was observed, which indicates the suppressive and destructive effect of microwave electromagnetic radiation of this term on cardiomyocytes.

Key words: heart, myocardium, thyroidectomy, hypothyroid state, microwave electromagnetic radiation.

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The Authors declare no conflict of interest.

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MORPHOFUNCTIONAL CHANGES OF THE MYOCARDIUM OF RATS AFTER THE EFFECT OF GENERAL AND LOCAL HYPOTHERMIA

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The results of the research at the microscopic level, after the effect of general hypothermia with a duration of exposure of 10 days, an increase in the size of cardiomyocytes, the interstitial space was found, which indicated the activation of adaptive processes of the microcirculatory bed and the energy supply apparatus of cells that occur in cardiomyocytes under the effect of general hypothermia with an early duration of action; with a term of action of 30 days – marked defibrillation of muscle fibers in the myocardium of the heart of the ventricles and the interventricular membrane of rats. The effect of local hypothermia using a cardioplegic solution for cooling the heart allows you to preserve the typical structure of the myocardium, while protecting the structural organization. Dry cooling of the heart causes destructive changes in the myocardium with the development of degenerative and destructive processes in the myocardium of the heart, in places muscle fiber breaks, myofibrils defibration, their destruction and an increase in intercellular spaces, which indicates the depressing effect and irreversible damage of this method of local hypothermia (dry cold) on the myocardium of the ventricles and interventricular membrane.

Key words: *heart, myocardium, thyroid gland, hypothyroidism, microwave electromagnetic radiation.*

Connection of the publication with planned research works. The research was carried out within the framework of the scientific topic of the department of human anatomy, clinical anatomy and operative surgery «Morphofunctional state of organs and tissues of experimental animals and humans in ontogenesis in normal and under the influence of external and internal factors», № state registration 0117U003181.

Introduction. According to the literature, the effects of some chemicals and hypothermia, in general, have been experimentally determined. Still, the effects of local and general hypothermia on the morphogenesis of the heart, especially under conditions of cooling, remain unexplored [1]. As for the influence of hypothermia, such an important question arises as the concepts of local and general cooling significantly impact the heart's morphogenesis. Direct observation of the effect of hypothermia on the structures of the heart in humans is impossible; therefore, with the help of induced experimental models, it becomes possible to analyze the morphological changes of the heart after exposure to cooling [2]. During the research, the role of modeling the pathological state, identifying the terms, causes, and mechanism of the formation of disturbances in the morphogenesis of the heart, its wall, and structural elements or components is increasing, which makes it possible to develop a model of hypothermia and will help to determine the corrective measures of cooling action. In the available literature, we could not find comprehensive studies using electrophysiological, general histological methods, immunohistochemistry, and electron microscopy of the myocardium in the pathology mentioned above [3, 4].

This substantiates the relevance of this research and the expediency of conducting it. According to the literature, hypothermia is when the internal body temperature drops below 35 degrees Celsius. Moderate therapeutic hypothermia procedures are used in post-cardiac arrest treatment, while surgical procedures often use lower core temperatures to provide cerebral protection [5]. An involuntary decrease in internal body temperature occurs with accidental hypothermia, and ventricular arrhythmias are considered the main cause of high mortality in these patients. Hypothermia is a relatively common clinical condition that is associated with significant morbidity and mortality, especially if it is not recognized and treated in time. This condition, associated with extreme changes in the body's internal temperature, can be accompanied by a violation of cardiac function, often with the apparent difference in the electrocardiogram [6, 7]. Many researchers are engaged in studying the morphology of organs under therapeutic effects, but the morphological modifications of these organs under