

Morphometric Changes of the Adrenal Glands Under the Influence of Carbon Monoxide

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Abstract This article is based on the results of an experimental scientific study conducted on 120 outbred white rats aged 6 and 12 months. During the study, morphometric changes in the adrenal glands were identified in both intact and carbon monoxide-exposed outbred white rats. Morphometric analysis of changes occurring in the adrenal gland tissue under chronic exposure to carbon monoxide represents one of the actual directions of modern medicine and contributes to solving and preventing endocrinological problems.

Keywords Carbon monoxide, Adrenal gland, Morphometry, Experiment, Rats

1. Introduction

According to researchers from leading scientific centers worldwide, the presence of 0.1% carbon monoxide in inhaled air can be fatal. According to data from the World Health Organization, currently 6–8% of human deaths occur as a result of poisoning by various gases. Carbon monoxide poisoning is one of the leading causes of death from acute chemical poisoning in many developed countries.

Carbon monoxide intoxication disrupts ontogenetically determined mechanisms regulating morphofunctional status, which leads to the loss of lateral dimorphism of the adrenal glands [1]. Such changes are assumed to have thanatogenetic significance. At the same time, the importance of morphofunctional changes in different parts of the adrenal gland and their contribution to the development of pathological processes remain insufficiently studied. The increase in mortality from adrenal gland diseases is also associated with the toxic effects of various exogenous factors, including carbon monoxide, on adrenal tissue, which necessitates further scientific research in this field [8].

In chronic carbon monoxide poisoning, the cardiovascular system is affected, manifesting as tachycardia, arrhythmia, extrasystole, and a tendency toward arterial hypotension. Gastrointestinal symptoms include loss of appetite, nausea, vomiting, diarrhea, gastritis, colitis, and possible liver dysfunction [2]. Visual disturbances include decreased visual acuity, especially in low light, impaired binocular vision and

accommodation, altered color perception, narrowing of visual fields, and fundus changes in the form of retinal vascular pathology of varying intensity [6,7]. There is also impairment of hearing and olfaction. Endocrine disturbances include thyroid dysfunction (hyperthyroidism) and decreased adrenal gland function.

Foreign researchers have studied changes in adrenal gland tissue under the influence of various drugs, developmental disorders due to intrauterine hypoxia, alterations in morphological parameters of adrenal tissue under the influence of ethyl alcohol, as well as the impact of stress factors and acute carbon monoxide poisoning on renal and adrenal tissues, leading to negative effects on adrenal function and changes in morphometric indicators [3,4,5].

Aim of the Study: The aim of this study was to investigate the morphometric parameters of the adrenal glands under chronic exposure to carbon monoxide.

2. Materials and Methods

The study was conducted in the research laboratory of the Bukhara State Medical Institute named after Abu Ali ibn Sina during 2025–2027.

The research was initiated according to a predefined plan that included all necessary stages and procedures required to conduct experiments and obtain reliable results. During the experimental process, ethical standards were strictly observed, and particular attention was paid to thorough planning. Determination of the research object and subject, as well as ensuring statistical reliability through an adequate sample size, was considered essential. Therefore, the study design was developed taking these requirements into account.

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The stages of the study were defined based on the principles of empirical medicine, including the selection of sample size, object, and research topic. At the initial stage, laboratory animals were bred and then randomly divided into experimental and control groups for subsequent experiments. Group representativeness was ensured, and feeding trials and preparatory procedures were carried out.

The experiments were conducted on 120 outbred white rats of both sexes, born under vivarium conditions. Rats aged 6 and 12 months were included. All procedures involving animals complied with ethical guidelines and the requirements of the Declaration of Helsinki. Before the start of the experiments, all sexually mature rats underwent a one-week quarantine period. After excluding somatic and infectious diseases, they were transferred to standard vivarium conditions.

Throughout the experiment, the behavior and physiological condition of animals in both control and experimental groups were continuously monitored. The rats were divided into three groups ($n = 120$): Group I – control ($n = 40$), Group II ($n = 40$), and Group III ($n = 40$).

Experimental animals were subjected to chronic carbon monoxide exposure at a concentration of 0.01–0.05 mg/L. During the experiment, 6 rats died as a result of chronic intoxication (2 aged 6 months and 4 aged 12 months).

In Group III ($n = 40$), rats exposed to chronic carbon monoxide intoxication additionally received, intragastrically via a metal gastric tube, 0.1 ml of an alcohol solution of asparagus oil (in a 1:9 ratio) for 14 days.

In total, 120 rats were used in the experiment, of which only 6 died during the study.

To model chronic carbon monoxide intoxication, rats aged 6 and 12 months were exposed to carbon monoxide in specially designed hermetic metal chambers at a concentration of 0.01–0.05 mg/L for 2 months. Rats in the control group received 1 ml of distilled water intragastrically via a metal gastric tube for 14 days.

During the experiment, observations were conducted on body weight dynamics, general condition, and behavior of the rats. No significant deviations in general condition or behavior were observed. Subsequently, experimental animals were weighed in the morning, euthanized under ether anesthesia by decapitation on an empty stomach, and included in further analysis.

Animal euthanasia was carried out in accordance with international guidelines for biomedical research involving laboratory animals.

The research methods included histomorphometric, histochemical, microscopic, immunohistochemical, and statistical analyses.

3. Results

In 12-month-old outbred white rats exposed to chronic carbon monoxide intoxication under experimental conditions, pronounced morphological and morphometric changes in the adrenal glands were observed. A marked decrease in adipocytes

in the periadrenal fat layer and irregular proliferation of connective (collagen) fibers were clearly evident.

The weight of the adrenal gland on one side ranged from 0.73 ± 0.12 g to 1.02 ± 0.11 g, with an average of 0.95 ± 0.42 g. Thickening of blood vessel walls, perivascular edema, and characteristic mucoid and fibrinoid swelling of the vascular walls were identified. These changes likely led to chronic hypoxia of the organ.

As a consequence, increased synthesis of tropocollagen by fibroblasts was observed, resulting in the proliferation of fibrous tissue, including in the pericellular regions. Additionally, the thickness of the adrenal capsule in 12-month-old rats increased, reaching an average of 3.7 ± 0.10 μm .

Proliferation of fibroblast cells in the capsule, along with the toxic effects of chronic carbon monoxide exposure and alterations in blood composition, was found to contribute to increased fibrosis of the gland. At the same time, a decrease in the number and size of cortical cells, as well as thickening of the intercellular barriers, was observed.

The thickness of the cortical layer ranged from 14.2 ± 0.15 μm to 17.1 ± 0.31 μm , with an average of 15.2 ± 0.16 μm . In the subcapsular region, underdeveloped cortical tissue was noted, where cambial cells and cells of the zona glomerulosa were reduced in size and showed atrophic changes.

The thickness of the zona glomerulosa ranged from 2.18 ± 0.08 μm to 6.28 ± 0.20 μm , with an average of 4.81 ± 0.24 μm . In the zona fasciculata, cells were reduced in size while their nuclei appeared enlarged. The thickness of this layer ranged from 6.24 ± 0.42 μm to 10.2 ± 0.25 μm , with an average of 8.05 ± 0.08 μm .

The thickness of the zona reticularis ranged from 2.36 ± 0.42 μm to 5.06 ± 0.25 μm , with an average of 4.75 ± 0.25 μm . In this zone, thickening of blood vessel walls was observed, along with lymphocytic infiltration in the perivascular areas and morphological changes in blood vessels characteristic of stasis.

The medullary region appeared reddish in color, with cells arranged in short cords and characterized by a high abundance of sinusoidal capillaries between them. The thickness of the medulla ranged from 14.53 ± 0.15 μm to 19.23 ± 0.37 μm , with an average of 17.24 ± 0.18 μm .

The walls of the sinusoidal blood vessels were thickened and showed mucoid swelling. Their lumens were filled with blood (plethora), accompanied by increased perivascular edema and lymphocytic infiltration. This lymphocytic infiltration was more pronounced at the boundary between the cortex and medulla, as well as in the perivascular areas of the medulla. As a result, cells in these regions became smaller, displaced toward the periphery, and underwent atrophic changes.

4. Conclusions

Under chronic carbon monoxide exposure, in 6-month-old rats, the thickness of the adrenal cortex decreased by up to 1.11 times compared to the control group. A reduction in cell

number, focal inflammation, and karyopyknosis in cell nuclei were observed.

In contrast, the medullary layer increased in thickness by approximately 1.14 times, mainly due to vascular congestion in sinusoidal vessels and perivascular edema. However, despite this increase, the size of medullary cells was reduced.

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