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MORPHOLOGICAL CHANGES IN CARDIAC TISSUE AFTER MECHANICAL TRAUMA UNDER GENERAL ANESTHESIA: AN EXPERIMENTAL ANALYSIS

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Abstract

This experimental study investigated morphological changes in rat heart tissue subjected to mechanical trauma under general anesthesia (nitrous oxide – N₂O). According to histological analysis, dystrophic changes in cardiomyocytes, karyolysis, cytolysis, focal necrosis, interstitial edema, venous congestion, and leukocytic infiltration were identified. These structural changes may impair cardiac function and are essential indicators for evaluating the effects of anesthesia. The study results are significant for early detection and prevention of cardiac complications in clinical practice.

Keywords: heart, morphological change, general anesthesia, N₂O, mechanical trauma, experiment.

Materials and Methods

The research was carried out at the Scientific Research Laboratory of the Bukhara State Medical Institute in accordance with institutional guidelines and ethical standards for the use of laboratory animals. The experimental model was based on the use of **30 clinically healthy, 9-month-old male and female albino rats**, each weighing between **200 to 250 grams**. These animals were bred and maintained under controlled conditions with a 12-hour light/dark cycle, standard pellet diet, and ad libitum access to water.

Prior to experimentation, all animals were acclimatized to laboratory conditions for 7 days. The rats were randomly allocated into two groups using a computerized randomization algorithm to ensure unbiased distribution and reduce potential selection bias:

- **Control Group (n = 10):** Animals in this group did not receive any mechanical trauma or anesthetic exposure. They were used to represent the normal, unaltered physiological state of cardiac tissue for baseline comparison.
- **Experimental Group (n = 20):** Animals were subjected to a controlled mechanical trauma, specifically a blunt impact directed to the soft muscle tissue of the right hind limb using a standardized calibrated device. Within 15 minutes

of injury induction, these rats were exposed to **general anesthesia via inhalation of nitrous oxide (N₂O)** at a clinical concentration for a duration of **120 minutes** in a sealed chamber with regulated airflow.

All procedures were approved by the Institutional Animal Ethics Committee and followed international standards for animal care (ARRIVE guidelines). At the end of the anesthesia period, animals were **humanely euthanized via cervical decapitation** to preserve tissue integrity for downstream histological assessment.

Immediately following euthanasia, the hearts were excised, rinsed in cold saline, and fixed in **10% buffered formalin** for 24 hours. Subsequently, standard **paraffin embedding** protocols were followed. Thin sections (4–5 µm) of cardiac tissue were obtained using a rotary microtome. The sections were stained with **hematoxylin-eosin (H&E)** to evaluate general histoarchitecture, **Van Gieson stain** to highlight connective tissue and collagen fibers, and **toluidine blue** for identifying acidic tissue components and metachromatic structures.

Microscopic evaluations were performed under a **Leica DM-LB light microscope** equipped with digital imaging. High-resolution images were captured for documentation and comparative analysis.

Morphometric analysis was conducted using the **DN-107T / Model NLSD-307B ocular micrometer (Nobel, China)**. Diameters of cardiomyocytes were measured across four cardiac regions: **right atrium, left atrium, right ventricle, and left ventricle**. For each animal, at least 20–25 cardiomyocytes were measured per anatomical location to ensure statistical relevance and accuracy.

Data obtained from morphometric measurements were subjected to statistical analysis using **GraphPad Prism 9** and **Microsoft Excel 2019**. Descriptive statistics were computed, including mean values and standard deviations. **Student's t-test** was applied to determine the statistical significance between control and experimental groups, with a **p-value < 0.05** considered statistically significant.

Results

In the **control group**, the cardiac tissues of rats exhibited **normal anatomical and histological architecture**. The myocardium was characterized by **uniformly aligned cardiomyocytes** with clearly distinguishable **central nuclei**, intact sarcoplasm, and **well-organized intercalated discs**. No histopathological signs of **edema, inflammatory infiltration, hemorrhage, fibrosis, or vascular abnormalities** were observed. The **diameters of arterioles and venules** were within physiological norms, and **connective tissue fibers** surrounding the myocardium were sparse and evenly distributed. Collagen fiber presence was minimal and restricted to the perivascular regions.

In contrast, significant **pathological changes** were documented in the **experimental group**, which underwent mechanical trauma followed by general anesthesia. Histological sections revealed **notable hypertrophy of cardiomyocytes**, evident from their **increased transverse diameter**, alongside **cytoplasmic vacuolization**, **nuclear pyknosis**, **karyolysis**, and **cytolysis**. These findings are indicative of cellular injury and early stages of myocardial degeneration.

The **interstitial compartment** showed **moderate to severe edema**, often separating adjacent muscle fibers. **Van Gieson staining** revealed a **notable increase in collagen deposition**, particularly in the perivascular and intercellular zones, suggestive of **reactive fibrosis**. **Toluidine blue staining** highlighted the presence of **granulocyte-dominant infiltration**, with **diffuse and focal accumulations** of **neutrophils and eosinophils**, indicating an acute inflammatory response.

Additionally, **venous congestion** was prominent in small and medium-caliber vessels, with **erythrocyte stasis** and **vascular dilation**. **Hemosiderin-laden macrophages** were occasionally observed, pointing to minor extravasation and degradation of erythrocytes. **Thickening of arterial walls**, with hyaline-like changes and partial luminal narrowing, suggested early-stage **arteriosclerosis**, possibly as a consequence of oxidative or mechanical stress induced by trauma and anesthesia.

Morphometric Analysis

Quantitative morphometric analysis confirmed statistically significant increases in **cardiomyocyte transverse diameters** in the experimental group compared to controls. Specifically:

- **Right atrium:** increased by **6.89%**
- **Left atrium:** increased by **3.4%**
- **Right ventricle:** increased by **10.25%**
- **Left ventricle:** increased by **3.63%**

These differences were consistent across the sampled regions and were statistically significant ($p < 0.05$). The findings indicate **regional susceptibility of cardiac structures**, with the right ventricle being more vulnerable to the combined effects of mechanical trauma and anesthetic-induced stress.

Anatomical Observation

In both groups, the **gross anatomical configuration** of the heart corresponded to standard rodent cardiac anatomy. The heart was **asymmetrically positioned** within the thoracic cavity, occupying a predominantly **left-sided** orientation relative to the midline. Its **apex directed caudally and ventrally**, with the base anchored near the **third to fifth costal cartilages**. The anterior surface of the heart was mostly covered by the lungs, leaving a narrow **cardiac notch** visible through the thoracic wall. No major anatomical displacements were noted in the control group, while **slight lateral deviation** of the apex toward the left side and **mild epicardial thickening** were

noted in several rats from the experimental group, likely due to **subclinical edema or connective tissue expansion**.

Conclusion

The combination of general anesthesia and mechanical trauma leads to significant morphological and histostructural alterations in cardiac tissue. Observed cardiomyocyte dystrophy, necrotic foci, and hemodynamic disorders are factors that diminish cardiac functional capacity. This study highlights the importance of cardiac monitoring in trauma patients under general anesthesia, enabling early identification of risk markers and development of preventive strategies. The findings are of practical importance in cardiology, anesthesiology, and experimental morphology.

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