WEB OF SCIENTIST: INTERNATIONAL SCIENTIFIC RESEARCH JOURNAL
ISSN: 2776-0979, Volume 7, Issue 5, May- 2026

MORPHOLOGICAL AND MORPHOMETRIC REMODELING CHARACTERISTICS OF THE AORTIC WALL UNDER EXPERIMENTAL METABOLIC SYNDROME (HIGH-FAT DIET MODEL)

Usmanov Ravshan Jahongirovich
Sultonova Gulnoza Zuhriddin qizi
Tashkent State Medical University

Abstract

In this study, structural and morphometric changes in the aortic wall under conditions of an experimental metabolic syndrome model induced by a high-fat diet were comprehensively evaluated. Pathomorphological processes developing in different layers of the vascular wall against the background of metabolic disturbances—particularly endothelial dysfunction, lipid infiltration, inflammatory responses, and extracellular matrix remodeling—were systematically analyzed.

The results demonstrated that the aortic wall was characterized by increased thickness, a significant expansion of the intima-media complex, disruption of elastic structural integrity, and an increase in collagen components. In addition, lipid accumulation in the subendothelial region and reorganization of cellular elements were identified, which were interpreted as features typical of the early stages of atherosclerotic processes.

The obtained data confirm that structural changes in the vascular wall under conditions of metabolic syndrome have a negative impact on its biomechanical properties and lead to increased arterial stiffness. These results provide an important scientific basis for a deeper understanding of the pathogenesis of vascular disorders associated with metabolic disturbances and for their early detection

Introduction

Metabolic syndrome is currently regarded in modern medicine as a complex set of pathophysiological processes and is considered one of the major risk factors for the development of cardiovascular diseases. This condition encompasses a combination of changes associated with reduced insulin sensitivity, disorders of lipid metabolism, increased arterial blood pressure, and abdominal obesity.

The aorta, as one of the central components of the vascular system, plays a key role in maintaining hemodynamic stability as an elastic-type artery. Its wall consists of three layers—intima, media, and adventitia—and the structural integrity of these layers determines the functional state of the vessel.

Against the background of metabolic disturbances, adaptive and maladaptive remodeling processes occur in the aortic wall. Such changes are closely associated with a reduction in the elastic properties of the vascular wall, an increase in stiffness, and the initiation of atherosclerotic processes.

From this perspective, a detailed study of the morphological and morphometric changes occurring in the aortic wall under conditions of metabolic syndrome is of significant importance for elucidating pathogenetic mechanisms and expanding the possibilities of early diagnosis.

Materials and Methods

The experimental study model involved induction of metabolic syndrome in laboratory mice using a high-fat diet (with a lipid content of 45–60% in the diet). The duration of the experiment was 12–16 weeks.

Morphological analysis of aortic specimens was performed using the following histological staining methods:

- Hematoxylin and eosin (H&E) — general histostructure assessment
- Masson's trichrome — visualization of collagen fibers
- Verhoeff–Van Gieson — evaluation of elastic fiber integrity

Morphometric evaluation was carried out using digital microscopy based on the following parameters:

- intimal and medial thickness
- adventitial thickness
- number and integrity of elastic lamellae
- collagen-to-elastin ratio

Statistical analysis was performed using Student's t-test, and a p-value of <0.05 was considered statistically significant.

Results

Integral Morphometric Remodeling of the Aortic Wall

Under the influence of a high-fat diet, the total thickness of the aortic wall increased significantly compared to the control group (52.3±4.6 μm → 84.1±6.8 μm; $p<0.05$). An 80% increase in the thickness of the intima-media complex indicates activation of pathological remodeling processes within the vascular wall.

Ultrastructural Changes in the Intima and Remodeling of the Media Layer

In the intimal layer, disruption of endothelial continuity, desquamation of endothelial cells, and surface irregularity were observed. Accumulation of lipid vacuoles and lipoprotein complexes was identified in the subendothelial region. The

formation and clustering of foam cells were recorded as morphological features characteristic of the early stages of atherogenesis.

In the medial layer, proliferation and phenotypic transformation of smooth muscle cells were observed. The cells transitioned from a contractile phenotype to a synthetic phenotype, resulting in increased synthesis of extracellular matrix components.

The following pathological changes were identified in the elastic lamellae:

• fragmentation and discontinuity
• structural disorganization
• widening of interlamellar spaces

A significant reduction in the number of elastic lamellae was noted, leading to a decrease in the elastic properties of the vascular wall.

Fibrotic Transformation of the Extracellular Matrix

Masson's trichrome staining demonstrated a significant accumulation of collagen fibers (18% → 35%; $p<0.01$). An increased collagen-to-elastin ratio reflects fibrotic remodeling of the vascular wall.

Inflammatory Changes in the Adventitial Layer

In the adventitia, fibroblast proliferation and densification of collagen fibers were observed, along with perivascular infiltration composed of macrophages and lymphocytes. These findings indicate the presence of a chronic inflammatory process.

Oxidative Stress and Molecular Damage

An increase in reactive oxygen species activates lipid peroxidation processes, leading to damage of cellular membranes and the endothelial layer. These processes further aggravate degenerative changes in the vascular wall.

Discussion

The obtained results demonstrate that morphological changes in the aortic wall under conditions of metabolic syndrome are complex and multistage in nature. The process begins with endothelial dysfunction and subsequently progresses through lipid infiltration, inflammation, and extracellular matrix remodeling.

These findings are consistent with the atherogenesis theory proposed by Russell Ross. The alterations observed in the medial layer can be explained by the phenotypic transformation of smooth muscle cells described by Gary K. Owens.

Degradation of elastic fibers and increased collagen deposition alter the biomechanical properties of the vascular wall, leading to increased arterial stiffness. This results in elevated hemodynamic load and contributes to cardiovascular system dysfunction.

Endothelial dysfunction observed in the intimal layer is considered an initial stage of vascular pathology. Disruption of endothelial cell integrity and intercellular junctions increases vascular permeability, facilitating the entry of lipid fractions into the subendothelial space. This process promotes lipid infiltration and foam cell formation, initiating atherogenesis.

Medial Layer Remodeling

The identification of smooth muscle cell proliferation and phenotypic transformation in the medial layer indicates their key role in vascular wall remodeling. Cells transitioning from a contractile phenotype to a synthetic phenotype actively synthesize extracellular matrix components, leading to wall thickening and the progression of fibrotic changes.

Fragmentation and disorganization of elastic lamellae have a direct impact on the biomechanical properties of the aortic wall. Degradation of elastin and increased collagen deposition reduce vascular elasticity and increase stiffness. This results in redistribution of hemodynamic load and causes functional strain on the cardiovascular system.

Adventitial Layer Changes

The inflammatory infiltration and fibrotic processes observed in the adventitial layer indicate the presence of a chronic inflammatory response in the vascular wall. Activation of macrophages and lymphocytes enhances cytokine release, which intensifies oxidative stress and deepens extracellular matrix degradation processes.

Oxidative Stress as a Key Mechanism

Increased oxidative stress is one of the main pathogenetic mechanisms in metabolic syndrome, activating lipid peroxidation, endothelial injury, and cellular apoptosis. These processes act synergistically, leading to the concurrent development of degenerative and proliferative changes in the vascular wall.

Conclusion of Discussion

Thus, the identified morphological and morphometric changes demonstrate that structural remodeling of the aortic wall under metabolic syndrome develops through complex pathogenetic mechanisms, and these processes constitute the morphological basis of atherosclerosis development.

Conclusion

1. A high-fat diet–induced metabolic syndrome leads to profound morphological remodeling of the aortic wall.
2. Increased thickness of the intima-media complex indicates vascular wall remodeling.
3. Degradation of elastic lamellae and collagen accumulation increase arterial stiffness.
4. Lipid infiltration and foam cell formation are early morphological markers of atherosclerosis.
5. Oxidative stress and inflammation are key pathogenetic mechanisms.
6. The high-fat diet–induced metabolic syndrome model causes deep and systemic morphological remodeling of the aortic wall, involving all layers of the vessel wall and disrupting their structural and functional integrity.
7. In the intima, endothelial dysfunction and increased lipid infiltration represent early stages of atherogenesis. In the media, smooth muscle cell proliferation and elastic lamellae degradation significantly alter the mechanical properties of the vessel wall. Increased collagen deposition and reduced elastin content in the extracellular matrix lead to fibrotic remodeling and increased arterial stiffness.
8. In the adventitia, inflammatory infiltration and fibrosis indicate a chronic inflammatory process in the vascular wall. Oxidative stress acts as an intensifying factor for these pathological changes.
9. Overall, morphological changes in the aorta under metabolic syndrome conditions lead not only to structural but also functional impairment. These alterations are closely associated with increased arterial stiffness, elevated hemodynamic load, and a higher risk of atherosclerosis development.

References

1 Grundy S.M. Metabolic syndrome pandemic // Circulation. – 2008. – Vol. 117. – No. 6. – P. 629–636.
2 Alberti K.G.M.M., Zimmet P., Shaw J. The metabolic syndrome – a new worldwide definition // Lancet. – 2005. – Vol. 366. – No. 9491. – P. 1059–1062.
3 Lusis A.J. Atherosclerosis // Nature. – 2000. – Vol. 407. – No. 6801. – P. 233–241.
4 Ross R. Atherosclerosis – an inflammatory disease // New England Journal of Medicine. – 1999. – Vol. 340. – No. 2. – P. 115–126.

5 Owens G.K., Kumar M.S., Wamhoff B.R. Molecular regulation of vascular smooth muscle cell differentiation // Physiological Reviews. – 2004. – Vol. 84. – No. 3. – P. 767–801.
6 Wagenseil J.E., Mecham R.P. Vascular extracellular matrix and arterial mechanics // Circulation Research. – 2009. – Vol. 104. – No. 6. – P. 745–756.
7 Laurent S., Boutouyrie P. Arterial stiffness and hypertension // European Heart Journal. – 2006. – Vol. 27. – No. 21. – P. 2588–2605.
8 Rizzoni D., Porteri E., Boari G.E. Structural alterations in subcutaneous small arteries // Hypertension. – 2003. – Vol. 41. – No. 3. – P. 406–412.
9 Schiffrin E.L. Remodeling of resistance arteries in essential hypertension // Hypertension. – 2004. – Vol. 43. – No. 5. – P. 1037–1042.
10 Buettner R., Schölmerich J., Bollheimer L.C. High-fat diets: modeling the metabolic disorders // Obesity. – 2007. – Vol. 15. – No. 4. – P. 798–808.
11 Madamanchi N.R., Vendrov A., Runge M.S. Oxidative stress and vascular disease // Arteriosclerosis, Thrombosis, and Vascular Biology. – 2005. – Vol. 25. – No. 1. – P. 29–38.
12 Davignon J., Ganz P. Role of endothelial dysfunction in atherosclerosis // Circulation. – 2004. – Vol. 109. – No. 23. – P. III27–III32.
13 Intengan H.D., Schiffrin E.L. Vascular remodeling in hypertension // Hypertension. – 2001. – Vol. 38. – No. 3. – P. 581–587.
14 Reaven G.M. Banting lecture: Role of insulin resistance // Diabetes. – 1988. – Vol. 37. – No. 12. – P. 1595–1607.
15 Motulsky H. Intuitive biostatistics. – New York: Oxford University Press; 2014.