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Morphofunctional Analysis of The State of The Rectum Under Stress (Literature Review)

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Abstract: Stress-induced changes in the rectum involve structural and functional alterations affecting its integrity and physiological role. This study examines histological modifications in the rectal wall under immobilization stress, emphasizing epithelial integrity, vascular reactions, and connective tissue remodeling. Morphometric analysis reveals mucosal atrophy, increased inflammatory infiltration, and microcirculatory disturbances. Functional assessments indicate impaired motility and altered mucus secretion, potentially predisposing to chronic pathologies. These findings highlight the significance of stress as a factor in colorectal dysfunction and emphasize the necessity of preventive measures to mi.

Keywords: Stress, rectum, morphofunctional analysis, histological changes, microcirculation, inflammatory infiltration, mucosal atrophy, motility, mucus secretion, colorectal dysfunction.

Introduction: The modern rhythm of life is characterized by a high stress load, which leads to an increase in the prevalence of stress-associated diseases, including pathologies of the gastrointestinal tract [60, 50]. The rectum, being the final part of the digestive system, is highly sensitive to neurohumoral influences and changes in the functional state of the body under stress. It is known that stress factors can lead to impaired motility, microcirculation, and the integrity of the intestinal mucosa, contributing to the development of inflammatory, degenerative, and functional changes. However, the morphofunctional mechanisms of stress-induced disorders in the rectum have not been sufficiently studied, which makes it difficult to develop effective methods for the prevention and correction of these conditions.

The purpose and objectives of the literary review. The purpose of this literature review is to analyze current data on morphofunctional changes in the rectum during stress, their pathogenetic mechanisms and possible consequences.

METHODS

This literature review is based on an analysis of modern scientific data on morphofunctional changes in the rectum under the influence of stress factors. The search and selection of sources were carried out using: Information resources: international and national databases (PubMed, Scopus, Web of Science, Google Scholar, eLibrary, etc.), analysis of publications over the past 10-15 years with the inclusion of key historical works on the topic, the use of original scientific articles, reviews, monographs and dissertations. Inclusion criteria: publications containing data on morphological and functional changes in the rectum under stress. Exclusion criteria: works with insufficient evidence base, duplicate results without new contribution to science.

RESULTS AND DISCUSSION

The rectum is the distal part of the large intestine that performs the final stages of digestion, accumulation, and evacuation of fecal matter. Its length in an adult is on average 12-15 cm, and the diameter varies depending on the condition of the filling. Anatomically, the rectum is divided into two main parts: ampullary and anal.

The wall of the rectum consists of several layers [38, 51]:

• The mucous membrane (tunica mucosa) is represented by a single—layered prismatic epithelium with goblet-shaped cells producing mucus necessary to facilitate the transit of intestinal contents. In the anal region, the epithelium is replaced by a multilayered flat keratinizing one.

• The submucosa base (tunica submucosa) contains a dense plexus of blood vessels and nerve endings, which makes this part of the intestine highly sensitive to various influences.

• The tunica muscularis is represented by two layers of smooth muscle fibers: the inner circular and the outer longitudinal. In the anorectal region, the circular layer thickens, forming the internal sphincter of the rectum.

• Serous and adventitious membranes — cover different parts of the intestine, depending on their location in the abdominal or pelvic cavity.

The rectum performs several key physiological functions:

1. Reservoir function — accumulation of fecal matter before defecation.

2. Evacuation function — participation in defecation due to the coordinated work of the muscles of the pelvic floor, abdominal press and anal sphincter.

3. The barrier function is to ensure the involuntary retention of intestinal contents between bowel movements due to the operation of the sphincter apparatus.

4. Reflex regulation — the susceptibility of mucosal receptors to mechanical and chemical stimuli affecting intestinal motility.

The role of the mucous membrane, nervous and vascular structures in ensuring its functioning

The mucous membrane of the rectum plays a central role in its function, providing:

• Mucus production to protect the epithelium from mechanical and chemical damage.

• Absorption of water and some electrolytes, which regulates the consistency of intestinal contents.

• Immune protection due to lymphoid elements in its own mucosal plate.

Nervous regulation is represented by a complex system:

• Autonomic innervation (sympathetic and parasympathetic) regulates muscle tone and secretion.

• Somatic innervation (via pudendal nerve) controls arbitrary components of bowel movements.

The vascular network provides an intensive blood supply:

Arterial nutrition is provided by the upper, middle and lower rectal arteries.

• Venous outflow through the rectal veins is associated with the portal vein system and the caval system, which predisposes to the development of hemorrhoids in hemodynamic disorders.

Mechanisms of stress and its effect on the body

Stress is a non—specific reaction of the body to the effects of various factors that disrupt homeostasis. Stressors can be classified according to their nature and mechanism of action. [16, 27, 1, 64, 68, 69, 2]:

1. Physical stressors are the effects of external factors affecting the body at the level of tissues and organs:

o Temperature changes (hypothermia, hyperthermia).

o Injuries, surgical procedures.

o Prolonged hypoxia or ischemia.

o Dehydration, electrolyte imbalance.

o Increased physical activity.

2. Emotional stressors are psychoemotional factors that lead to changes in the nervous and endocrine systems.:

o Social and interpersonal conflicts.

o Chronic anxiety, depression.

o Information overload, stress at work.

3. Physiological stressors – internal processes that cause a stress reaction:

o Diseases, inflammatory processes.

o Hormonal disorders.

o Prolonged starvation, lack of nutrients.

o Disturbance of sleep and circadian rhythms.

Each of these factors can trigger complex adaptive mechanisms, leading to changes in various organs, including the gastrointestinal tract and rectum.

The key mechanism of the stress response is the activation of the hypothalamic-pituitary-adrenal (HPA) axis, the endocrine system that regulates the body's adaptation to adverse effects [66, 67, 48, 61, 13, 57, 71].

1. Initiation of a stress response

In response to stressful factors, the hypothalamus produces corticotropin-releasing hormone (CRH), which stimulates the anterior pituitary gland.

The pituitary gland secretes adrenocorticotropic hormone (ACTH), which activates the adrenal cortex.

The adrenal glands secrete glucocorticoids (cortisol), which regulate metabolism, immune response, and adaptive mechanisms.

2. Long-term exposure to glucocorticoids

Increased cortisol levels lead to immunosuppression, catabolic processes, and dysregulation of inflammatory responses.

In the gastrointestinal tract, this contributes to atrophic changes in the mucous membrane, increased epithelial permeability, and microcirculation dysfunction.

Stimulation of the sympathetic nervous system increases peristalsis and secretion, which can cause hypermotor or, conversely, intestinal hypotension.

The HGH axis plays a central role in the pathogenesis of stress-induced lesions of the gastrointestinal tract, including the formation of morphofunctional changes in the rectum.

Stress can be acute (short-term exposure to a stressor) or chronic (prolonged exposure to adverse factors) [33, 17, 23, 5, 34, 65].

1. Acute stress

- Activation of the sympatho-adrenal system → release of adrenaline and norepinephrine.

Increased blood circulation, increased blood pressure.

- Intestinal hyperperistalsis, possible cramps, diarrhea.

- Accelerated metabolism, mobilization of energy reserves.

2. Chronic stress

Prolonged exposure to glucocorticoids causes atrophic and inflammatory processes in the gastrointestinal mucosa.

- Microcirculation disorders lead to tissue ischemia, which contributes to the development of ulcers and erosions.

Changes in neurohumoral regulation lead to dysfunction of intestinal motility, which can manifest as irritable bowel syndrome (IBS).

An imbalance of the autonomic nervous system (hyperactivation of sympathetic or parasympathetic regulation) can lead to persistent functional disorders of the gastrointestinal tract.

Thus, stress is a powerful trigger contributing to the development of morphofunctional changes in the rectum, and its mechanisms should be taken into account when developing preventive and therapeutic strategies.

Stress has a pronounced effect on the mucous membrane of the rectum, causing morphological and functional disorders. Studies show that under the influence of chronic stress, there is a thinning of the epithelium, a violation of the integrity of the mucous barrier and the development of erosive and ulcerative processes. Degenerative changes are accompanied by a decrease in the number of goblet cells producing protective mucus, which makes the mucosa more vulnerable to aggressive factors. [19, 21, 31, 42].

Inflammatory processes in response to stress are

mediated by the activation of immune cells and the release of pro-inflammatory cytokines such as interleukin-1b (IL-1b), tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6). These mediators contribute to infiltration of the mucosa by leukocytes, increased epithelial permeability and destruction of intercellular contacts, which exacerbates inflammatory reactions and increases the risk of secondary infectious complications. [18, 22, 55, 49].

One of the key mechanisms of stress-induced changes in the rectum is a violation of microcirculation. Under the influence of stress factors, the sympathoadrenal system is activated, which leads to vascular spasm and decreased blood flow in the intestinal wall. Tissue hypoxia caused by prolonged ischemia contributes to the accumulation of reactive oxygen species (ROS), which triggers the processes of oxidative damage to cells. [14, 28, 39, 43].

Increased vascular permeability is accompanied by extravasation of plasma and shaped blood elements into the interstitial space, which leads to edema and disruption of the structural integrity of tissues. Prolonged hypoperfusion exacerbates inflammatory processes by activating the transendothelial migration of leukocytes and enhancing the damaging effects of free radicals.

Stress has a significant effect on the nervous regulation of the motor function of the rectum. Dysfunction of the enteric nervous system leads to disruption of coordinated peristaltic contractions, which manifests itself in the form of hyper- or hypomotor disorders [3, 15, 29]. Hyperactivity of the sympathetic nervous system under stress causes inhibition of intestinal motility, which contributes to stagnation of intestinal contents, impaired bowel movements and the development of constipation. At the same time, a number of patients have the opposite reaction – increased parasympathetic activity, which leads to hypermotor activity, increased bowel movements and diarrhea.

In addition, stress affects the sensitive nerve endings in the mucous membrane, which can lead to visceral hypersensitivity and pain in the rectum.

At the cellular level, stress effects activate the processes of programmed cell death (apoptosis), which is accompanied by loss of epithelial cells and impaired barrier function of the mucosa. The proapoptotic proteins of the Bcl-2 family, as well as the activation of the caspase cascade, play an important role in this process.

Oxidative stress is one of the leading mechanisms of cell damage during stress. Increased formation of reactive oxygen species (ROS) and decreased activity of antioxidant systems (superoxide dismutase, catalase, glutathione peroxidase) leads to damage to lipids of cell membranes, proteins and DNA.

Chronic stress is also accompanied by an imbalance of inflammatory mediators, which contributes to the maintenance of a long-term inflammatory process in the mucous membrane and increases its vulnerability to adverse factors. Thus, stress has a complex effect on the morphofunctional state of the rectum, leading to structural and functional changes that may be the pathogenetic basis of various intestinal disorders.

The development of inflammatory bowel diseases under stress

Stress has a significant impact on the gastrointestinal tract, including the rectum. One of the key consequences of chronic stress exposure is the development of inflammatory diseases such as proctitis and colitis. [46, 12, 19, 21].

Chronic stress causes activation of the hypothalamic-pituitary-adrenal system (HPA), which leads to hyperproduction of glucocorticoids and catecholamines. These hormones, in turn, contribute to:

• Dysfunction of the intestinal barrier, increasing its permeability and facilitating the penetration of pathogens.

• Disruption of the local immune response, which leads to increased inflammatory processes.

• Activation of oxidative stress, which damages epithelial cells and increases the production of proinflammatory cytokines (TNF-α, IL-6, IL-1b).

Studies show that stress can provoke an exacerbation of inflammatory bowel diseases, as well as play a significant role in their pathogenesis, especially in the presence of a genetic predisposition.

The role of stress in the pathogenesis of irritable bowel syndrome (IBS)

Irritable bowel syndrome (IBS) is a functional disorder characterized by impaired intestinal motility, abdominal pain, and changes in stool patterns. Stress is considered one of the key factors that initiates and supports the symptoms of IBS. [58, 9, 11, 53].

The relationship between stress and IBS

• Imbalance of the autonomic nervous system. Increased activity of the sympathetic nervous system against the background of stress leads to hyperactivity of the intestine or, conversely, its spasm.

• Changes in visceral sensitivity. Stress increases pain perception by activating central perception mechanisms, which increases pain in patients with IBS.

• Microbiome disorders. Changes in the composition of

the intestinal microflora against the background of stress contribute to the development of dysbiosis, which worsens the intestinal barrier function and promotes inflammation.

• Impaired serotonergic regulation. Serotonin plays a key role in regulating intestinal motility, and stress affects its metabolism, which can lead to diarrhea or constipation.

Clinical studies confirm that patients with IBS are more likely to experience stressful conditions, and psychotherapeutic methods (cognitive behavioral therapy, relaxation techniques) improve their condition along with traditional medical approaches.

Long-term effects of stress damage to the rectal mucosa

Chronic stress exposure leads to persistent structural and functional changes in the rectal mucosa, which may increase the risk of developing various pathologies [20, 36].

The main consequences

1. Atrophic and degenerative changes

Prolonged activation of stress mechanisms leads to depletion of the regenerative potential of the mucous membrane.

- There is a decrease in the number of goblet cells responsible for the production of protective mucus.

The development of microerosions and a decrease in the height of the villi, which impairs the absorption processes.

2. Increased permeability of the mucous membrane

Violation of the integrity of intercellular junctions leads to an increase in the permeability of the intestinal barrier, which contributes to the penetration of bacterial toxins and the development of chronic inflammation.

3. Fibrosis and decreased elasticity of the intestinal wall

Prolonged inflammation and oxidative stress contribute to active fibrosis.

This can lead to a violation of the motility of the rectum, the formation of constipation and a decrease in its functional activity.

4. The risk of precancerous changes

- Chronic inflammation, oxidative stress and hyperproduction of proinflammatory cytokines create conditions for malignant transformation of mucosal cells.

- Studies show that prolonged stress exposure can increase the risk of epithelial dysplasia and colorectal cancer.

Thus, chronic stress not only provokes inflammatory diseases of the rectum, but can also contribute to their progression, as well as the formation of precancerous conditions. This highlights the need for a comprehensive approach to correcting stress-induced changes, including both drug-based and non-drug prevention methods.

Various morphological, histochemical, functional and biochemical methods are used for a comprehensive analysis of changes that occur in the rectum under the influence of stress factors. Their combination makes it possible to identify structural and functional disorders at the cellular and molecular levels. [54, 70, 7, 10].

Histological examination is a key method for assessing morphological changes in the tissues of the rectum. Staining of sections with hematoxylin and eosin makes it possible to detect epithelial damage, inflammatory infiltrates, and vascular structure disorders. Special colors (PAS-reaction, toluidine blue) make it possible to analyze changes in mucin-producing cells and the degree of degranulation of mast cells involved in stress-associated inflammatory reactions.

Immunohistochemical analysis is used to detect specific proteins associated with inflammation, apoptosis, and stress-induced changes. Markers of inflammation (COX-2, NF-kB), apoptosis (caspase-3, Bcl-2), oxidative stress (SOD, iNOS), and mucosal barrier permeability (Occludin, Claudin-1) are used.

Transmission and scanning electron microscopy methods make it possible to study ultrastructural changes in cells and intercellular contacts that occur under the influence of stress. Examination at the subcellular level reveals the destruction of mitochondria, the separation of dense contacts between epithelial cells, damage to microvilli and the accumulation of autophagic vacuoles. These changes indicate a violation of the barrier function of the mucous membrane and increased processes of cellular stress and apoptosis.

Stress has a significant effect on motor activity and secretion of the rectum, which can be assessed using various functional tests. [8, 47, 30, 6, 25].

• Manometry is used to analyze intestinal motility, detect peristalsis disorders and spasms characteristic of stress-induced disorders.

• Electrogastroenterography is a method of recording the bioelectric activity of the intestine, which makes it possible to assess changes in the contractile function of smooth muscle cells.

• Mucus secretion study — quantitative analysis of secreted mucins (MUC2, MUC4) to assess changes in the barrier function of the mucous membrane.

• Permeability of the intestinal barrier is determined using tests with markers such as lactulose/mannitol coefficient, which makes it possible to detect a violation of the integrity of the epithelium under the influence of stress.

Important information about the state of the rectum under stress is provided by biochemical parameters reflecting the level of inflammation and oxidative tissue damage [62, 4, 56].

• Inflammatory marker enzymes: cyclooxygenase-2 (COX-2), interleukins (IL-1b, IL-6), tumor necrosis factor-α (TNF-α), which are involved in stress-induced inflammatory reactions.

• Indicators of oxidative stress: activity of superoxide dismutase (SOD), catalase (CAT), malondialdehyde (MDA) level as an indicator of lipid peroxidation.

• Markers of apoptosis and cell damage: the level of caspase-3, expression of proteins p53 and Bcl-2, indicating the induction of programmed cell death.

• Intestinal microbiota and its metabolites: analysis of changes in the composition of microflora and the concentration of short-chain fatty acids (SCFA), which play an important role in protecting the mucous membrane from stress-induced damage.

The combined use of these methods makes it possible to obtain an objective picture of morphofunctional changes in the rectum under stress, identify key pathogenetic mechanisms and identify possible approaches to their correction.

Modern approaches to the prevention and correction of stress-induced changes in the rectum

Pharmacological correction of stress-induced changes in the rectum is aimed at stabilizing the functional state of the mucous membrane, reducing inflammation, and improving neurohumoral regulation [40, 45, 26].

• Neuroprotectors are drugs that affect the central and autonomic nervous systems, reducing the effects of stress on the regulation of intestinal motility and the barrier function of the mucous membrane. These include adaptogens (melatonin, phenotropil), anxiolytics (afobazole, grandaxin), and drugs that regulate serotonergic transmission (trittico, selective serotonin reuptake inhibitors).

• Antioxidants – reduce oxidative stress, which is one of the key mechanisms of mucosal damage during chronic stress. Preparations based on alpha-lipoic acid, vitamin E, coenzyme Q10, as well as natural antioxidants (curcumin, resveratrol) are used.

• Anti–inflammatory drugs are aimed at suppressing inflammatory processes that occur in response to stress. Nonsteroidal anti-inflammatory drugs (ibuprofen, nimesulide) are used in limited doses, as well as pro-inflammatory cytokine inhibitors (infliximab, adalimumab) in case of pronounced pathological changes.

Non-drug approaches

Alternative methods of correcting the effects of stress have a complex effect, helping to restore the balance of the microbiota, reduce inflammation and improve the adaptive capabilities of the body. [52, 59, 44, 24].

• Diet Therapy – dietary recommendations are aimed at restoring the intestinal barrier and reducing inflammation. Preference is given to foods rich in fiber (vegetables, fruits, whole grains), polyunsaturated fatty acids (fish, flaxseed oil) and probiotic cultures (yoghurts, kefir). The consumption of simple carbohydrates, refined foods and alcohol is limited.

• Probiotics and prebiotics – contribute to the normalization of intestinal microflora, which reduces the negative effects of stress on intestinal permeability and inflammation. The most effective strains are Lactobacillus and Bifidobacterium, as well as prebiotics (inulin, fructooligosaccharides) that stimulate the growth of beneficial bacteria.

• Psychotherapy and stress management - cognitive behavioral therapy methods, meditation and breathing practices can reduce the level of chronic stress by reducing its effect on the intestines. Mindfulness, biofeedback, and autotraining techniques are considered effective.

Promising areas of research

Despite a significant amount of research, many aspects of the effect of stress on the morphofunctional state of the rectum remain insufficiently studied [41, 32, 63, 35].

• Genetic and epigenetic mechanisms of stress-associated changes – studying the expression of genes regulating the inflammatory response and barrier function of the mucosa will allow a deeper understanding of the mechanisms of intestinal adaptation to stress.

• The role of the microbiome in the formation of stress-induced disorders – in-depth studies of the interaction of intestinal microflora with the nervous and immune systems will open up new opportunities for probiotic and metabiotic correction.

• Development of new pharmacological drugs – promising areas are selective neuroinflammation modulators, drugs that affect the intestinal endocannabinoid system, as well as innovative antioxidant complexes.

• Personalized prevention strategies – the use of multiomic technologies (metagenomics, metabolomics)

to select individual treatment regimens and prevent stress-induced disorders.

These areas of research will allow not only to better understand the mechanisms of stress effects on the rectum, but also to develop more effective methods of protection and therapy.

CONCLUSION

An analysis of the literature data indicates a significant effect of stress factors on the morphofunctional state of the rectum. Stress induces disturbances in microcirculation, leading to hypoxia and increased vascular permeability, which contributes to the development of inflammatory and destructive changes in the mucous membrane. Morphological studies confirm the presence of degenerative processes such as epithelial atrophy, destabilization of intercellular contacts and activation of apoptosis. Functional disorders caused by stress include changes in the motility of the rectum, manifested by discoordination of peristalsis, cramps or hypomtility, which can contribute to the development of proctogenic constipation or diarrhea. An imbalance of autonomic regulation, accompanied by changes in the secretion of neurotransmitters and cytokines, exacerbates pathological processes, creating conditions for the formation of chronic inflammatory bowel diseases.

Thus, stress has a complex effect on the morphological and functional parameters of the rectum, involving neuroendocrine, vascular and immune mechanisms. These processes can contribute to the development of stress-associated pathologies such as irritable bowel syndrome, chronic proctitis and colitis.

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