AMERICAN ACADEMIC PUBLISHER

INTERNATIONAL JOURNAL OF MEDICAL SCIENCES

ISSN NUMBER: 2692 - 5206 Volume 5. No 11. November ,2025

ASSESSMENT OF THE IMPACT OF THYMECTOMY ON CYTOGENETIC INDICES OF BONE MARROW

Sharipova Riboba Gulomalievna

Bukhara state medical institute

Abstract: The aim of the study was to compare cytogenetic changes in the bone marrow of outbred rats after thymectomy in an experimental setting and to adequately interpret the obtained results. A total of 80 white outbred rats, aged 3 months and weighing 160–180 g, were randomly selected for the study. The results demonstrated that thymectomy exerts a negative effect on bone marrow cells at the molecular level, leading to an increase in mitotic abnormalities and enhanced apoptosis against the background of reduced proliferative activity of cells, along with a decrease in the number of metaphases and prophase. These changes contribute to the development of cytogenetic alterations and intensify cytotoxic effects, while increased apoptosis raises the likelihood of DNA mutations in cells.

Keywords. Thymus, thymectomy, bone marrow, cytogenetic indices.

ОЦЕНКА ВЛИЯНИЯ ТИМЭКТОМИИ НА ЦИТОГЕНЕТИЧЕСКИЕ ПОКАЗАТЕЛИ КОСТНОГО МОЗГА

Шарипова Рибоба Гуломалиевна
Бухарский государственный медицинский институт

Аннотация. Целью исследования было сопоставить цитогенетические изменения в костном мозге беспородных крыс после тимэктомии в экспериментальных условиях и адекватно интерпретировать полученные данные. Для эксперимента случайным образом было отобрано 80 белых беспородных крыс возрастом 3 месяца и массой 160–180 г. Результаты показали, что тимэктомия оказывает отрицательное воздействие на клетки костного мозга на молекулярном уровне, приводя к увеличению числа митотических нарушений и усилению апоптоза на фоне сниженной пролиферативной активности клеток, сокращения числа метафаз и профаз. Эти изменения способствуют возникновению цитогенетических нарушений и усилению цитотоксического эффекта, при этом повышение апоптоза увеличивает вероятность мутаций в ДНК клеток.

Ключевые слова. Тимус, тимэктомия, костный мозг, цитогенетические показатели.

The thymus is one of the central organs of the immune system, where T-lymphocyte proliferation and differentiation occur, ensuring cellular immunity within the immune system. In addition, the hormones of this organ play a crucial role in the functioning of both the body and its immune system. Its removal leads to deficiencies in cellular and humoral immunity, resulting in secondary immunodeficiency [1, 2, 6].

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 5. No 11. November ,2025

Considering that the bone marrow is also a central organ of the immune system, it is evident that it participates in maintaining the organism's resistance. Although these organs are located in different anatomical regions, they are functionally interconnected with the peripheral organs of the immune system, ensuring hematopoiesis and immune defense processes [3, 10].

Cytogenetic research is known as the study of the qualitative and quantitative characteristics of chromosome sets in the organism's cells. It evaluates the impact of various external and internal factors on the human karyotype and identifies different pathological conditions [5, 12].

Chromosomes are tightly packed DNA strands that store information about the organism's genome. In humans, somatic cell nuclei contain 46 chromosomes (23 pairs), of which 22 pairs are autosomes and 1 pair is sex chromosomes, determining the individual's sex [8, 11].

To investigate the relationship between central immune organs and identify changes within them, experimental thymectomy was used, and molecular alterations in the bone marrow of laboratory animals were studied using cytogenetic analysis. White outbred rats were chosen for the experiment because, as mammals, their chromosome set is similar to that of humans (46 chromosomes – 23 pairs). Cytogenetic changes observed in these animals can therefore provide insight into analogous conditions in humans.

The aim of the study was to comparatively investigate cytogenetic changes in the bone marrow of white outbred rats following thymectomy and to adequately interpret the obtained results.

Materials and Methods. A total of 80 three-month-old white outbred rats weighing 160–180 g were randomly selected for the study. The standard vivarium diet was formulated based on the feeding norms recommended by Nuraliev N.A. et al. [7]. All procedures regarding animal housing, euthanasia, and surgical interventions adhered to biological safety regulations and ethical principles for working with laboratory animals [9].

Thymectomy in white outbred rats was performed according to Victoria R. Rendell et al. [13]. This method reliably ensured complete thymectomy while minimizing operative time and perioperative mortality.

All laboratory animals were divided into four representative experimental groups:

1. Main group 1 – thymectomized rats without "Lactopropolis-AWL," n=20.
2. Main group 2 – thymectomized rats receiving "Lactopropolis-AWL," n=20.
3. Comparison group – thymectomized rats receiving ASD-2, n=20.
4. Control group – intact rats without thymectomy, probiotics, or biostimulants, n=20.

"Lactopropolis-AWL" is a probiotic composed of live antagonistic microbial biomass of *Lactobacillus casei* 925 and *Propionibacterium avidum*, combined with 1% dry propolis extract. It is registered as a biologically active supplement (BAS) by the Ministry of Health of the Republic of Uzbekistan. The probiotic is produced by the Microbiology Institute of the Academy of Sciences of Uzbekistan and AllWellLab LLC. This probiotic positively influences the normal

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 5. No 11. November ,2025

intestinal microflora, exhibiting antimicrobial, immunostimulatory, and anti-inflammatory properties. The dose administered to rats (0.3 mL/day per rat for 14 days) was based on the recommendations of Nuraliev N.A. et al. [9], given in two daily doses (2×10^7 CFU/mL per strain).

ASD-2 (Dorogov's Antiseptic-Stimulant) is a biologically active substance developed in the 1940s. It is obtained from animal proteins through special thermal distillation. The active component of ASD-2 is an adaptogenic substance released before cell death. ASD-2 appears as a liquid, black-yellow to reddish in color, with a characteristic sharp odor (unpleasant for most people) and is easily soluble in water and other liquids. This substance exerts the following effects in animals and humans: stimulates immune function, accelerates tissue regeneration, has anti-inflammatory and antiseptic properties, promotes detoxification, and helps balance hormonal activity. It is manufactured by the Armavir Biopharmaceutical Plant (Russian Federation) and is registered as a veterinary preparation.

For the cytogenetic study, the femur bones were collected from white outbred rats during euthanasia, and the bone marrow was isolated. Cytogenetic changes were directly assessed using standard methods. In each sample, 15–25 cells with metaphase plates were counted under a microscope, and the obtained numbers were analyzed. The number of cells observed in the preparations was recorded under the microscope, and the mitotic index (MI) was calculated using the formula: MI=Number of dividing cells/1000×100

The study material was statistically processed using both parametric and non-parametric analysis methods. Data organization and visualization were performed in Microsoft Office Excel 2016 spreadsheets, and statistical analysis was carried out using IBM SPSS Statistics v.26. Randomization, representativeness, and evidence-based medicine principles were strictly followed during the study.

Results and Discussion. To obtain a clear understanding of all indicators, cytogenetic study results from intact (control group) and thymectomized animals (main group 1) were examined. Comparative analysis of the data is presented in Table 1.

Table 1

Cytogenetic parameters of bone marrow in white outbred rats after thymectomy, %

Parameters	Experimental groups	
	Control group, n=20	1-Main group, n=20
Proliferative activity of bone marrow cells, %	36,67	28,61 ↓
Number of metaphases, %	51,68	36,14 ↓
Number of prophase cells, %	39,35	26,01 ↓
Normal metaphase plates, %	79,98	49,34 ↓
Severe spiralization, C-mitosis, aneuploidy, polyploidy, %	22,54	47,66 ↑

AMERICAN ACADEMIC PUBLISHER

INTERNATIONAL JOURNAL OF MEDICAL SCIENCES

ISSN NUMBER: 2692 - 5206 Volume 5. No 11. November ,2025

Cell death by apoptosis, %	5,20	8,57 ↑
Cell death by necrosis, %	0,83	0,83 ↔

Note: ↑, ↓ – directions of change; ↔ – no significant difference.

The study of the effect of thymectomy on cytogenetic parameters in bone marrow showed that in intact animals, the proliferative activity of bone marrow cells was 36.67%, whereas after thymectomy, this parameter decreased to an average of 28.61%, representing a significant reduction of 1.28 times.

It is known that increased proliferative activity reflects the rate and degree of cell division. This process occurs continuously during the physiological regeneration of all tissues. Its decrease occurs under increased functional stress or tumor development, while a reduction is observed under atrophic processes and various pathological effects [4]. If the surgical removal of the thymus is considered a pathological impact, the observed decrease in bone marrow proliferation in thymectomized animals can be evaluated as a natural consequence. Notably, cell proliferation in thymectomized animals was inhibited by 8.06% compared to the control group.

The study revealed that the average number of metaphases in intact white nonbred rats was 51.68%, whereas in thymectomized animals, it decreased 1.43 times, representing a reduction of 15.54%.

Since metaphase is the second stage of mitosis, during which chromosomes align at the cell equator, quantitative changes in metaphase reflect mitotic disruption and can lead to chromosomal abnormalities. Thus, thymectomy leads to a decrease in metaphase numbers, indicating a cytotoxic effect. Cytotoxicity represents a harmful effect of various external influences on cells, causing profound functional and structural changes and ultimately leading to cell death. This effect also concerns bone marrow cells, another central organ of the immune system.

In addition to metaphase, prophase numbers in bone marrow cells were studied. Prophase is the first stage of mitosis, during which DNA molecules condense and undergo spiraling to form compact chromosomes. Each chromosome consists of two DNA molecules connected at the centromere. During this stage, the nuclear envelope disintegrates, and chromosomes occupy the cytoplasm. Centrioles move toward opposite poles of the cell in preparation for division.

In this study, prophase numbers in bone marrow cells varied. In intact laboratory animals, this parameter was 39.35%, whereas in thymectomized animals, it decreased 1.51 times, or by 13.34%, representing a significant reduction.

Thus, cytogenetic studies of bone marrow in thymectomized white nonbred rats (primary experimental group 1) showed that out of the seven studied parameters, four were significantly lower than in intact laboratory animals (control group). Two parameters increased due to the pathological effect, while one parameter showed no practical difference. Proliferative activity of bone marrow cells in thymectomized animals decreased by 1.28 times, or 8.06%, compared to intact animals. Metaphase numbers decreased by 1.43 times, or 15.54%, and prophase numbers decreased by 1.51 times, or 13.34%.

These findings indicate that thymectomy reduces proliferative activity in bone marrow cells and induces various cytogenetic changes. This confirms the functional connection between the thymus and bone marrow, demonstrating that thymus removal has a direct negative effect on bone marrow cells. Additionally, mitotic arrest at the prophase and metaphase stages was observed.

Alongside the numbers of prophase and metaphase cells, metaphase plates were also examined under a light microscope. Metaphase plates are formed by chromosomes aligned at the cell equator and are also referred to as equatorial plates. Normally, this stage of mitosis proceeds without pathological changes; however, various influences can lead to pathological alterations in the metaphase plates, which can be detected during microscopic examination.

In this study, metaphase plates were found to be normal in 79.98% of cases in intact laboratory animals, while pathological signs were observed in the remaining 20.02%. In contrast, in thymectomized animals, the proportion of normal metaphase plates decreased significantly to 49.34%, with pathological metaphase plates increasing to 50.66%. Compared to intact animals, the proportion of normal metaphase plates in thymectomized animals decreased 1.62 times, or by 30.64%. This indicates a negative effect of thymectomy on the metaphase plates of bone marrow cells, suggesting that thymectomy indirectly affects bone marrow at the molecular level.

Currently, it is known that various mitotic abnormalities, such as colchicine metaphases (C-mitosis), aneuploidy, polyploidy, and excessive chromosomal spiraling, can be detected during microscopic analysis.

C-mitosis occurs when mitosis is delayed or completely halted during metaphase, typically due to the effect of colchicine or other C-mitotic agents. This condition is accompanied by chromosome condensation.

Aneuploidy involves an abnormal number of chromosomes in the cell, deviating from the normal haploid set, and is considered a major mitotic pathology. Polyploidy, characterized by the quantitative multiplication of the haploid chromosome set, is another example of mitotic abnormalities.

Chromosome condensation and coiling during cell division is referred to as chromosomal spiraling. This ensures proper alignment of chromosomes at the cell poles and normally occurs during prophase. However, external influences can increase spiraling intensity, which serves as a marker of pathology.

In this study, mitotic abnormalities in bone marrow cells were observed in an average of 22.54% of cases in intact animals (control group). After thymectomy (primary experimental group 1), these abnormalities increased 2.11 times, or by 25.12%, reaching an average of 47.66%. This clearly indicates that thymectomy increases the frequency of mitotic pathologies.

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 5. No 11. November ,2025

Other cytogenetic parameters showed partial changes in apoptosis-type cell death, whereas necrosis-type cell death did not demonstrate a significant difference. In intact and thymectomized animals, necrotic cell death was 5.20% and 8.57%, respectively, with each nucleus showing 0.83%.

Thus, cytogenetic analysis of bone marrow cells in thymectomized white rats (primary experimental group 1) revealed a significant increase in the frequency of pathological metaphase plates. Compared to intact animals, the proportion of normal metaphase plates decreased 1.62 times, or by 30.64%. This confirms the negative molecular-level effect of thymectomy on bone marrow cells. Correspondingly, mitotic abnormalities (C-mitosis, aneuploidy, polyploidy, and excessive chromosomal spiraling) increased, rising 2.11 times, or by 25.12% relative to intact animals.

Additionally, apoptosis-type cell death increased 1.65 times compared to intact animals, whereas necrosis-type cell death showed no significant difference between groups (0.83%). The decrease in bone marrow cell proliferation activity, along with reduced numbers of meta- and prophase cells, the increase in mitotic abnormalities, and the elevation of apoptosis demonstrate a profound effect of thymectomy on bone marrow cells, confirming its negative molecular-level impact. This leads to enhanced cytogenetic alterations, increased cytotoxic effects, and a higher probability of DNA damage due to intensified apoptotic processes.

Similar studies were conducted in thymectomized animals receiving the "Lactopropolis-AWL" dietary supplement for biocorrection. Each rat in the second experimental group received 0.3 g/kg of the supplement for 14 days, added to their morning feed (porridge). For comparison, cytogenetic analysis of bone marrow cells was performed in intact (control group) and thymectomized (primary experimental group 1) white rats. The results are presented in Table 2.

Table 2

Comparative indicators of cytogenetic changes in bone marrow cells after thymectomy, %

Parameters	Experimental groups		
	Control group, n=20	1-Main group, n=20	2-Main group, n=20
Proliferative activity of bone marrow cells, %	36,67	28,61 ↓	22,10 ↓
Number of metaphases, %	51,68	36,14 ↓	46,42 ↓
Number of prophase cells, %	39,35	26,01 ↓	32,66 ↓
Metaphase plates without pathology, %	79,98	49,34 ↓	31,10 ↓
Severe chromosomal spiraling, C-mitosis, aneuploidy, polyploidy, %	22,54	47,66 ↑	36,24 ↑
Cell death by apoptosis, %	5,20	8,57 ↑	20,92 ↑
Cell death by necrosis, %	0,83	0,83 ↔	0 ↔

Note: ↑, ↓ – direction of change; ↔ – no statistically significant difference.

In previous studies, it was demonstrated that out of the seven parameters of bone marrow cells examined in cytogenetic analysis, six (85.71%) showed negative changes (four decreased, two increased), while only one (14.29%) remained unchanged. This finding served as evidence of a mesonic relationship between the thymus and bone marrow. The results from the second experimental group showed a similar trend, although the intensity of changes differed.

When comparing the parameters of the second experimental group with the intact (control) animals, the proliferative activity of bone marrow cells was found to have decreased 1.66-fold, or by 14.57%. This inhibition of activity was confirmed to result from thymectomy. Similar results were observed for the numbers of metaphases and prophase cells, which decreased by 1.11-fold (5.26%) and 1.20-fold (6.69%), respectively. The proportion of cells with normal metaphase plates also decreased significantly in the second experimental group, by 2.57-fold, or 48.88%.

When comparing the second experimental group with the first experimental group, the changes occurred in different directions: while the proliferative activity of bone marrow cells continued to decrease (by 6.51%), the numbers of metaphases and prophase cells increased by 10.28% and 6.65%, respectively. In contrast, the proportion of normal metaphase plates decreased by 18.24%. Additionally, while mitotic pathologies decreased by 11.42%, apoptosis-type cell death increased significantly.

The differences between the first and second experimental groups were characterized by a reduction in pathological mitotic features and an increase in apoptosis. These results indicate that biocorrection using "Lactopropolis-AWL" did not show a pronounced effect.

Thus, assessing the degree of cytogenetic changes in the bone marrow cells after thymectomy revealed that the trends in the thymectomized animals subjected to biocorrection (second experimental group) were similar to those in the first experimental group and differed from intact controls, with negative cytogenetic changes observed. Compared to the first experimental group, the intensity of changes varied and occurred in different directions. The proliferative activity of bone marrow cells decreased 1.66-fold (14.57%), while the numbers of metaphases and prophase cells increased by 1.11-fold (5.26%) and 1.20-fold (6.69%), respectively. The proportion of normal metaphase plates deteriorated, decreasing 2.57-fold (48.88%), while mitotic pathologies decreased by 11.42% and apoptosis increased by 12.35%. These findings indicate that "Lactopropolis-AWL" did not demonstrate a clearly effective response.

Similar studies were conducted in thymectomized animals with correction using the ASD-2 biostimulator. The results are presented in Table 3.

Table 3

Comparative parameters (%) of cytogenetic changes in bone marrow cells after thymectomy.

Parameters	Experimental groups

AMERICAN ACADEMIC PUBLISHER

INTERNATIONAL JOURNAL OF MEDICAL SCIENCES

ISSN NUMBER: 2692 - 5206 Volume 5. No 11. November ,2025

	Control, n=20	1-Main, n=20	2-Main, n=20	comparative , n=20
Bone marrow cell proliferation activity, %	36,67	28,61 ↓	22,10 ↓	34,85 ↔
Number of metaphases, %	51,68	36,14 ↓	46,42 ↓	45,87 ↓
Number of prophase cells, %	39,35	26,01 ↓	32,66 ↓	38,43 ↔
Pathology-free metaphase plates, %	79,98	49,34 ↓	31,10 ↓	51,07 ↓
Severe chromosomal spiraling, C-mitosis, aneuploidy, polyploidy, %	22,54	47,66 ↑	36,24 ↑	48,93 ↑
Cell death by apoptosis, %	5,20	8,57 ↑	20,92 ↑	15,23 ↑
Cell death by necrosis, %	0,83	0,83 ↔	0 ↔	0,83 ↔

Note: ↑, ↓ – directions of change; ↔ – no significant difference observed.

It is known that laboratory animals included in the comparison group received the ASD-2 biostimulator for 14 days prior to thymectomy. Post-thymectomy data were then studied and evaluated as short-term results (1 month).

The obtained results were interpreted and analyzed in comparison with the parameters of intact laboratory animals (control group). All indicators were noteworthy, and most importantly, they showed results distinct from the other experimental groups (Primary Group 1 and Primary Group 2). Out of the 7 parameters studied, 3 (42.86%) remained within the range of intact animals' parameters and did not differ significantly in practical terms.

These included the proliferative activity of bone marrow cells (34.85% vs. 36.67%), the number of prophase cells (38.43% vs. 39.35%), and cell death by necrosis (0.83%). The differences between them ranged only from 0.92% to 1.82%.

However, for the remaining parameters, significant differences similar to those seen in the previous groups were observed. In the comparison group, the number of metaphase cells decreased by 1.13 times (5.81%) relative to intact animals, and the number of metaphase plates in a normal, pathology-free state decreased by 1.57 times (28.91%).

Similar to other experimental groups, mitotic pathology remained high in the comparison group—48.93% vs. 22.54% (difference of 2.17 times or 26.39%). The high incidence of mitotic pathology (severe spiralization, C-mitosis, aneuploidy, polyploidy) was associated with the performed thymectomy, since other external and internal factors that could influence this were eliminated to ensure experimental purity.

The increase in apoptosis-related cell death was also observed in the comparison group—15.23% vs. 5.20% (2.93 times or a 10.03% difference in favor of the comparison group).

When comparing these parameters with the experimental groups, it became clear that for all indicators (except apoptosis and necrosis-related cell death), the values obtained were higher than those of Primary Groups 1 and 2. This was especially true for bone marrow cell

AMERICAN ACADEMIC PUBLISHER

INTERNATIONAL JOURNAL OF MEDICAL SCIENCES

ISSN NUMBER: 2692 - 5206 Volume 5. No 11. November ,2025

proliferative activity, the number of prophase cells, and the number of metaphase plates in a normal state.

Only the mitotic pathology indicators were somewhat worse, although the difference was not significant. Therefore, in the comparison group, cytogenetic changes in bone marrow were relatively weak, cytotoxic effects were underdeveloped, no structural chromosomal changes were detected, and the higher apoptosis rate could potentially lead to DNA alterations.

Thus, evaluation of post-thymectomy cytogenetic changes in bone marrow cells showed that in the comparison group (thymectomy + ASD-2), 3 of the 7 studied parameters (42.86%) remained within the range of intact animals' parameters. These were bone marrow cell proliferative activity, the number of prophase cells, and necrosis-related cell death, with differences ranging from 0.92% to 1.82%. The number of metaphase cells decreased by 1.13 times (5.81%) and the number of normal metaphase plates by 1.57 times (28.91%) compared to intact animals. Mitotic pathology remained high (difference of 2.17 times or 26.39%) and was linked to thymectomy. The increase in apoptosis was also observed (2.93 times or 10.03% in favor of the comparison group).

Therefore, cytogenetic changes in bone marrow of comparison group animals were relatively mild, cytotoxic effects were underdeveloped, no structural chromosomal changes were detected, and the high rate of apoptosis could potentially lead to DNA alterations.

Conclusions:

1. In thymectomized white non-inbred rats, 4 of the 7 cytogenetic parameters in bone marrow were significantly lower than those in intact animals, 2 were higher due to pathological conditions, and 1 showed no significant difference.

2. Bone marrow cell proliferative activity decreased by 1.28 times (8.06%), metaphases by 1.43 times (15.54%), and prophase cells by 1.51 times (13.34%) in thymectomized animals compared to intact ones. This indicates that thymectomy reduces proliferative activity and leads to various cytogenetic changes. Mitotic progression in prophase and metaphase stages was also inhibited.

3. The number of normal metaphase plates in thymectomized rats decreased by 1.62 times (30.64%), demonstrating the negative molecular effect of thymectomy on bone marrow cells. Mitotic pathology increased 2.11 times (25.12%), apoptosis increased 1.65 times, while necrosis-related cell death did not differ between groups (0.83%).

4. The decrease in proliferative activity, reduction in metaphase and prophase cells, increased mitotic pathology, and enhanced apoptosis indicate that thymectomy negatively affects bone marrow cells at the molecular level, leading to cytogenetic changes, increased cytotoxic effects, and a higher likelihood of DNA alterations due to apoptosis.

5. In thymectomized and biocorrected animals (Primary Group 2), the trend of changes was similar to that of Primary Group 1 (thymectomy only), differing from intact animals, with negative cytogenetic changes observed. Cytogenetic changes due to cytotoxic effects were pronounced, and the intensity of changes varied compared to Primary Group 1. This demonstrates that "Lactopropolis-AWL" was clearly ineffective.

AMERICAN ACADEMIC PUBLISHER

INTERNATIONAL JOURNAL OF MEDICAL SCIENCES

ISSN NUMBER: 2692 - 5206 Volume 5. No 11. November ,2025

6. In the comparison group (thymectomy + ASD-2), 3 of the 7 studied parameters (proliferative activity, prophase cell number, necrosis-related cell death) remained within the range of intact animals, with differences of 0.92–1.82%. Thus, cytogenetic changes were relatively weak, cytotoxic effects were underdeveloped, no structural chromosomal changes were detected, and the high apoptosis rate could potentially lead to DNA alterations.

References

1. Antônio J.M. Cataneo, Gilmar Felisberto Jr. and Daniele C. Cataneo Thymectomy in nonthymomatous myasthenia gravis - systematic review and meta-analysis // Orphanet Journal of Rare Diseases. – 2018. - N13. – 99.

2. Victoria R. Rendell, Charles Giamberardino, Jie Li, M. Louise Markert, Todd V. Brennan Complete Thymectomy in Adult Rats with Non-invasive Endotracheal Intubation // JoVE Journal Immunology and Infection. – 2014. – N6.

3. Директива 2010/63/EU Европейского парламента и Совета Европейского союза по охране животных, используемых в научных целях. - СПб.: Rus-LASA «НП объединение специалистов по работе с лабораторными животными». - 2012. - 48 с.

4. Игамова О.К., Нуралиев Н.А. Тажрибавий тимэктомия ўтказилган лаборатория ҳайвонлари иммун тизими параметрларининг динамикадаги ўзгаришлари тавсифи // Замонавий тиббиёт журнали. - Андижон, 2024. - №4(07). – 276-283 б.

5. Игамова О.К., Нуралиев Н.А. Тимэктомия ўтказилган тажриба ҳайвонлари гуморал иммунитети ва цитокин статусининг тавсифи // Гуманитар ва табиий фанлар журнали. – Тошкент, 2024. - №14(09). - 91-97 б.

6. Керея А.В., Гостюхина А.А., Межерицкий С.А., Большаков М.А., Зайцев К.В., Кутенков О.П., Ростов В.В. Пролиферативная активность клеток костного мозга крыс после облучения наносекундным импульсно-периодическим микроволновым излучением // Современные вопросы биомедицины. – 2019. – Т. 3. – №. 2 (7). – С. 6-22.

7. Макаров В.Г., Макарова М.Н. Справочник. Физиологические, биохимические и биометрические показатели нормы экспериментальных животных. СПБ: Изд-во «Лема». - 2013. - 116 с.

8. Нуралиева У.М. Выявление причины развития дисбиоза кишечника у тимэктомированных лабораторных животных в эксперименте // Журнал гуманитарных и естественных наук. - Ташкент, 2024. - № 8 (03). - С.160-164.

9. Нуралиев Н.А., Бектимиров А.М-Т., Алимова М.Т., Сувонов К.Ж. Правила и методы работы с лабораторными животными при экспериментальных микробиологических и иммунологических исследованиях // Методическое пособие. – Ташкент. - 2016. - 34 с.

10. Нуралиев Н.А., Хомидова С.Х. Иммунология. Ўқув қўлланма. – Бухоро, 2023. – 157 б.

11. Нуралиев Н.А., Эргашев В.А., Исмоилов Э.А. Экспериментал тадқиқотларда лаборатория ҳайвонлари билан ишлашнинг этик тамойиллари: шарҳ // Nazariy va klinik tibbiyot jurnali. – Тошкент, 2017. - №4. - 21-23 б.

12. Пасюк А.А. Сравнительная характеристика строения и топографии долей тимуса человека и белой крысы // Медицинский журнал. - 2018. - №3. - С.118-122.

AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES
ISSN NUMBER: 2692 - 5206 Volume 5. No 11. November ,2025

13. Полевщиков А.В. Новые данные по иммунофизиологии тимуса // Журнал теоретической и клинической медицины. - Ташкент, 2018. - №4. - С.136-138.