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*Egamberdieva Zarina Daniyarovna,
Amonov Aminjon Shavkatovich
Tashkent State Medical University
Tashkent, Uzbekistan*

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SCREENING FOR OBSTRUCTIVE SLEEP APNEA SYNDROME IN CHILDREN WITH CONGENITAL HEART DEFECTS IN A CARDIOLOGY INPATIENT SETTING

Abstract.

This study investigates the prevalence and clinical impact of obstructive sleep apnea syndrome (OSAS) in children with congenital heart defects (CHD) in a cardiology inpatient setting. A prospective observational study was conducted involving 100 children aged 1-12 years with confirmed CHD. Comprehensive cardiological assessment and stepwise screening for sleep-disordered breathing, including nocturnal portable polysomnography, were performed. OSAS was detected in 41% of patients, with moderate to severe forms present in 24%. Children with OSAS exhibited significantly higher pulmonary artery pressure, increased right heart overload, more frequent nocturnal tachycardia, and reduced exercise tolerance compared to those without OSAS. Correlation analysis demonstrated a dose-dependent relationship between apnea-hypopnea index, oxygen desaturation, and pulmonary hemodynamic impairment. Longitudinal follow-up over 18 months revealed that correction of sleep-disordered breathing improved oxygenation, reduced apnea-hypopnea episodes, stabilized pulmonary artery pressure, and decreased hospitalization rates. The findings indicate that OSAS is a clinically significant, modifiable risk factor that exacerbates the course of CHD in children. Systematic screening and timely management of OSAS should be considered integral to pediatric cardiology care to optimize hemodynamic status and long-term prognosis.

Keywords: *Sleep apnea, congenital heart defects, pulmonary hypertension, pediatric cardiology, polysomnography*

Introduction. Obstructive sleep apnea syndrome (OSAS) in children is a significant and potentially modifiable risk factor for cardiorespiratory complications. In children with congenital heart defects (CHD), recurrent nocturnal hypoxemia, hypercapnia, and sleep fragmentation lead to persistent activation of the sympathetic system, endothelial dysfunction, and increased pulmonary vascular resistance. These pathophysiological mechanisms promote the development and progression of pulmonary hypertension (PH), thereby aggravating the underlying cardiac condition.

Despite this established link, OSAS in children with CHD is frequently underdiagnosed, as clinical manifestations of sleep-disordered breathing are often masked by cardiac symptoms. Intermittent nocturnal hypoxemia triggers endothelial dysfunction, oxidative stress, and elevated production of vasoconstrictive mediators. In children with CHD, these effects compound pre-existing congenital circulatory abnormalities, creating conditions for early onset or worsening of pulmonary hypertension.

Even moderate OSAS can induce clinically significant increases in pulmonary artery pressure in patients with underlying cardiac disease, highlighting its role as a modifiable risk factor. Correcting OSAS may improve hemodynamic parameters and slow progression of heart failure.

However, in real-world clinical practice, OSAS screening is rarely incorporated into standard cardiology assessments. As a result, many children are monitored and treated for their cardiac disease without addressing sleep-disordered breathing, a key contributor to disease progression.

Systematic screening for OSAS in children with CHD is therefore an urgent interdisciplinary challenge. Implementing a standardized screening protocol can improve early detection, guide timely intervention, and ultimately enhance prognosis and quality of life.

Materials and Methods. The aim of this study was to assess the prevalence of obstructive sleep apnea syndrome in children with congenital heart defects and to determine its impact on pulmonary hemodynamic parameters. The study was designed as a prospective, single-center, observational investigation with a follow-up period of 18 months. A total of 100 children with confirmed congenital heart defects who were hospitalized and treated in a cardiology department were enrolled in the study. The age of the patients ranged from 1 to 12 years, with a mean age of 6.8 ± 2.9 years. Acyanotic congenital heart defects were diagnosed in 85% of cases, while cyanotic defects were observed in 15% of patients.

All participants underwent comprehensive cardiological evaluation, including echocardiographic assessment of pulmonary artery pressure, evaluation of signs of right heart overload, determination of the functional class of heart failure, and analysis of hospitalization frequency. Screening for sleep-disordered breathing was conducted in a stepwise manner and included a structured parental interview focusing on snoring, observed apneas, and restless sleep, followed by nocturnal portable polysomnography with assessment of the apnea-hypopnea index, minimum oxygen saturation, oxygen desaturation index, and frequency of nocturnal tachycardia. Obstructive sleep apnea syndrome was diagnosed when the apnea-hypopnea index was ≥ 1 episode

per hour, with subsequent classification according to severity. Statistical analysis was performed using descriptive methods and correlation analysis based on Pearson's correlation coefficient. Differences were considered statistically significant at $p < 0.05$.

Results. The study included 100 children with congenital heart defects aged from 1 to 12 years, with a mean age of 6.8 ± 2.9 years. The structure of cardiac defects was dominated by acyanotic forms, which accounted for 85% of cases, whereas cyanotic heart defects were diagnosed in 15% of patients. Signs of heart failure corresponding to functional class II-III were identified in 38% of the examined children.

According to the results of stepwise screening, sleep-disordered breathing was detected in 41% of patients. Mild obstructive sleep apnea syndrome was diagnosed in 17% of children, moderate in 15%, and severe in 9%. Thus, clinically significant forms of OSAS, including moderate and severe disease, were observed in nearly one quarter of the entire study cohort. The highest prevalence of OSAS was noted among children with combined and cyanotic congenital heart defects.

Analysis of sleep parameters demonstrated that in children with OSAS, the mean apnea-hypopnea index was 6.9 ± 3.8 episodes per hour, whereas in patients without sleep-disordered breathing it did not exceed 0.6 ± 0.3 episodes per hour ($p < 0.001$). The minimum oxygen saturation level during sleep in patients with OSAS decreased to $82.4 \pm 6.1\%$, while in children without OSAS this parameter remained at $91.3 \pm 3.8\%$ ($p < 0.001$). The oxygen desaturation index was more than six times higher in the OSAS group compared with the control group, indicating the presence of pronounced intermittent hypoxemia.

Assessment of pulmonary hemodynamics revealed statistically significant differences between the groups. The mean pulmonary artery pressure in children with OSAS was 36.8 ± 6.4 mmHg, whereas in patients without sleep-related breathing disorders it was 26.2 ± 5.1 mmHg ($p < 0.001$). In 72% of children with moderate and severe OSAS, pulmonary artery pressure values met the diagnostic criteria for pulmonary hypertension. Signs of right heart overload were detected in 63% of patients with OSAS, which was more than

twice as high as in children without OSAS (28%, $p < 0.01$).

Correlation analysis demonstrated a pronounced dose-dependent relationship between the severity of sleep-disordered breathing and pulmonary hemodynamic parameters. A significant positive correlation was identified between the apnea-hypopnea index and pulmonary artery pressure ($r = 0.62$, $p < 0.001$), as well as between the oxygen desaturation index and pulmonary artery pressure ($r = 0.55$, $p < 0.001$). At the same time, a statistically significant inverse correlation was observed between minimum nocturnal oxygen saturation and pulmonary artery pressure ($r = -0.58$, $p < 0.001$). Graphical data analysis confirmed the linear nature of these associations.

The clinical course of congenital heart defects in children with OSAS was characterized by greater severity. In this group, episodes of nocturnal tachycardia were recorded significantly more frequently (58% versus 22%), along with reduced exercise tolerance and a higher functional class of heart failure. The annual hospitalization rate in patients with OSAS was 2.6 ± 0.4 episodes per year, compared with 1.5 ± 0.3 episodes in children without sleep-disordered breathing ($p < 0.01$).

Dynamic follow-up over 18 months after the implementation of systematic screening and correction of sleep-disordered breathing demonstrated clinically meaningful improvement in several parameters. Mean AHI values decreased by 1.7-fold, while minimum nocturnal oxygen saturation increased by an average of 6-8%. In 61% of patients with baseline pulmonary hypertension, stabilization or reduction of pulmonary artery pressure was documented. The rate of recurrent hospitalizations decreased by 28% compared with baseline values.

Overall, the results indicate a high prevalence of obstructive sleep apnea syndrome in children with congenital heart defects and confirm its significant impact on sleep-related respiratory parameters, pulmonary hemodynamics, and the clinical course of the underlying disease. The study cohort was representative in terms of age and sex distribution, with a predominance of acyanotic forms of congenital heart defects (Tables 1-4).

Table 1.

Clinical Characteristics of Examined Children with Congenital Heart Defects

(n = 100)

| Parameter | Value |
|--------------------------------------|----------------|
| Age, years (M \pm SD) | 6.8 \pm 2.9 |
| Age range | 1-12 years |
| Boys, n (%) | 54 (54%) |
| Girls, n (%) | 46 (46%) |
| Acyanotic CHD, n (%) | 85 (85%) |
| Cyanotic CHD, n (%) | 15 (15%) |
| Signs of CHF (FC II-III), n (%) | 38 (38%) |
| Mean pulmonary artery pressure, mmHg | 30.6 \pm 7.8 |

The study cohort is representative by age and sex. The predominance of acyanotic CHD reflects the common distribution of congenital defects. Nearly 40% of

children exhibit moderate heart failure, indicating baseline hemodynamic compromise.

Table 2.

Prevalence and Severity of Obstructive Sleep Apnea Syndrome in Children with Congenital Heart Defects

| OSAS Severity | Criterion (AHI, events/hour) | n | % |
|---------------|------------------------------|----|----|
| No OSAS | <1.0 | 59 | 59 |
| Mild | 1.0-5.0 | 17 | 17 |
| Moderate | 5.1-10.0 | 15 | 15 |
| Severe | >10.0 | 9 | 9 |
| Total OSAS | ≥1.0 | 41 | 41 |

OSAS affects 41% of the cohort, with 24% presenting moderate to severe disease. This confirms that clinically significant sleep-disordered breathing is

common in children with CHD and may contribute to disease progression.

Table 3.

Pulmonary Hemodynamics and Cardiac Parameters According to the Presence of Obstructive Sleep Apnea Syndrome

| Parameter | OSAS (n = 41) | No OSAS (n = 59) | p |
|---------------------------------|---------------|------------------|--------|
| Pulmonary artery pressure, mmHg | 36.8 ± 6.4 | 26.2 ± 5.1 | <0.001 |
| Pulmonary hypertension, n (%) | 29 (72%) | 11 (19%) | <0.001 |
| Right heart overload, % | 63 | 28 | <0.01 |
| CHF functional class ≥ II, % | 51 | 24 | <0.01 |

Children with OSAS demonstrate significantly higher pulmonary artery pressures, more frequent pulmonary hypertension, and increased right heart overload. This highlights the hemodynamic impact of sleep-disordered breathing in CHD patients.

Correlation analysis demonstrated a dose-dependent relationship between the severity of sleep-disor-

dered breathing and pulmonary hemodynamic parameters. Specifically, there was a positive association between AHI and pulmonary artery pressure, as well as between the oxygen desaturation index and pulmonary artery pressure, and an inverse association between minimum nocturnal oxygen saturation and pulmonary artery pressure (Table 4).

Table 4.

Correlation Between Sleep Parameters and Pulmonary Hemodynamics

| Parameters | r | p |
|---|-------|--------|
| AHI ↔ Pulmonary artery pressure | 0.62 | <0.001 |
| Minimum SpO ₂ ↔ Pulmonary artery pressure | -0.58 | <0.001 |
| Oxygen desaturation index ↔ Pulmonary artery pressure | 0.55 | <0.001 |

There is a dose-dependent relationship between OSAS severity and pulmonary hemodynamics. Higher AHI and desaturation index correlate with elevated pulmonary artery pressure, while lower minimum SpO₂ is associated with worse pulmonary hypertension.

Correction of OSAS resulted in reduced AHI, improved oxygen saturation, decreased pulmonary artery pressure, and lower hospitalization rates. This confirms that sleep-disordered breathing is a modifiable risk factor influencing both hemodynamic and clinical outcomes in children with CHD.

Discussion. The present study provides strong evidence that obstructive sleep apnea syndrome (OSAS) is a clinically significant factor aggravating congenital heart defects (CHD) in children. The prevalence of OSAS in our cohort was 41%, substantially higher than in the general pediatric population, highlighting the increased vulnerability of children with CHD to sleep-disordered breathing. Nearly one quarter of patients had moderate to severe OSAS, accompanied by pronounced intermittent hypoxemia, with minimum nocturnal oxygen saturation below 85% and elevated oxygen desaturation index, indicating a chronic nocturnal hypoxic burden that may exacerbate congenital hemodynamic abnormalities.

A key finding is the dose-dependent relationship between OSAS severity and pulmonary hemodynamics. Apnea-hypopnea index (AHI) positively correlated with pulmonary artery pressure, while minimum oxygen saturation inversely correlated with pulmonary pressure, indicating that the magnitude of sleep-disordered breathing, rather than its mere presence, determines the degree of hemodynamic impact. These results align with the concept of intermittent hypoxemia as a major trigger of pulmonary vascular dysfunction.

Our findings are consistent with prior studies. Gozal et al. (European Respiratory Journal) emphasized that recurrent nocturnal hypoxic episodes activate endothelial dysfunction, oxidative stress, and increase pulmonary vascular tone, with accelerated progression in children with underlying cardiac pathology. Kheirandish-Gozal and Gozal reported persistent alterations in vascular tone regulation and impaired nocturnal sympathetic withdrawal in pediatric OSAS, which superimposes on pre-existing right ventricular overload-consistent with the high prevalence of right heart overload in our OSAS cohort. Data from Circulation and the Journal of the American College of Cardiology further indicate that even moderate OSAS is an inde-

pendent risk factor for pulmonary hypertension progression, and its correction can partially reverse hemodynamic abnormalities, in line with our longitudinal observations.

Clinically, children with OSAS experienced more frequent hospitalizations, nocturnal tachycardia, and higher functional classes of heart failure, demonstrating that OSAS affects both subclinical and clinically relevant outcomes. The 18-month follow-up confirmed that these abnormalities are modifiable: reduction in AHI, improvement in oxygenation, and stabilization of pulmonary artery pressure were observed following OSAS correction. These findings support systematic screening and interdisciplinary management, as emphasized by the American Academy of Sleep Medicine and the European Respiratory Society.

Overall, OSAS should be considered not merely a comorbidity, but a pathogenetically significant factor contributing to pulmonary hypertension progression and worsening of CHD in children. Incorporating sleep-disordered breathing screening into standard cardiology protocols in inpatient settings is both justified and clinically necessary.

Conclusions. The present study provides evidence that obstructive sleep apnea syndrome (OSAS) is highly prevalent in children with congenital heart defects (CHD), affecting 41% of patients in a cardiology inpatient setting. Clinically significant forms of OSAS, including moderate and severe disease, were observed in 24% of the cohort, accompanied by pronounced intermittent hypoxemia and disruption of sleep architecture.

Severity of OSAS was directly associated with pulmonary hemodynamic impairment: the apnea-hypopnea index (AHI) and oxygen desaturation index positively correlated with pulmonary artery pressure ($r = 0.62$ and $r = 0.55$, respectively, $p < 0.001$), while minimum nocturnal oxygen saturation showed a negative correlation ($r = -0.58$, $p < 0.001$). Children with OSAS demonstrated higher prevalence of right heart overload (63% vs. 28%), more frequent nocturnal tachycardia (58% vs. 22%), reduced exercise tolerance, and increased hospitalization rates (2.6 ± 0.4 vs. 1.5 ± 0.3 episodes/year, $p < 0.01$).

Longitudinal follow-up over 18 months revealed that correction of OSAS led to significant improvement in respiratory and hemodynamic parameters: mean AHI decreased by 1.7-fold, minimum nocturnal oxygen saturation increased by 6-8%, pulmonary artery pressure

stabilized or decreased in 61% of patients with baseline pulmonary hypertension, and hospitalization rates declined by 28%.

These findings confirm that OSAS is a clinically significant, dose-dependent, and modifiable risk factor that exacerbates the course of CHD in children. Systematic screening, timely diagnosis, and interdisciplinary management of OSAS should be considered essential components of pediatric cardiology care, with the potential to optimize pulmonary hemodynamics, improve clinical outcomes, and enhance long-term prognosis.

References

1. Gozal D. Sleep-disordered breathing and school performance in children. *Pediatrics*. 1998;102(3):616-620.
2. Kheirandish-Gozal L, Gozal D. Pediatric obstructive sleep apnea: A potential risk factor for cardiovascular disease. *European Respiratory Journal*. 2012;39(5):1280-1291.
3. Marcus CL, Brooks LJ, Draper KA, et al. Diagnosis and management of childhood obstructive sleep apnea syndrome. *Pediatrics*. 2012;130(3):576-584.
4. Goldstein NA, Aronin C, Kantrowitz B, et al. The prevalence of sleep-disordered breathing in children with congenital heart disease. *Journal of Clinical Sleep Medicine*. 2015;11(11):1249-1256.
5. Amin RS, Kimball TR, Bean JA, et al. Left ventricular hypertrophy and abnormal ventricular geometry in children and adolescents with obstructive sleep apnea. *American Journal of Respiratory and Critical Care Medicine*. 2002;165(10):1395-1399.
6. Эгамбердиева З.Д. Анализ методов диагностики и лечения обструктивного апноэ сна у детей // The 6th International Scientific and Practical Conference "World science: problems, prospects and innovations", February 23-25, 2021, Toronto, Canada. - 2021. - С. 756.
7. Larkin EK, Rosen CL, Kirchner HL, et al. Variation of pulmonary artery pressure in children with sleep-disordered breathing. *Chest*. 2002;122(5):1685-1691.
8. Simonneau G, Montani D, Celermajer DS, et al. Haemodynamic definitions and updated clinical classification of pulmonary hypertension. *European Respiratory Journal*. 2019;53(1):1801913.

*Idiev Zohid Ziyodullaevich,
Nurmukhamedova Firuza Baxtiyorovna
Tashkent State Medical University
Tashkent, Uzbekistan
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A PROSPECTIVE STUDY OF ENDOSCOPIC SURGICAL TECHNIQUES FOR CHRONIC RHINOSINUSITIS IN CHILDREN BASED ON EPOS 2020 GUIDELINES

Abstract.

In this article, the effectiveness of endoscopic surgical techniques for the treatment of chronic rhinosinusitis (CRS) in children is investigated based on EPOS 2020 guidelines. A prospective study was conducted involving 100 patients aged 8–16 years who underwent comprehensive clinical, endoscopic, and computed tomography (CT) evaluation, including Lund–Mackay scoring and SNOT-22 assessment. Patients were divided into two groups: the main group underwent a modified minimally invasive functional endoscopic sinus surgery (FESS) with partial uncinctomy and mucosa-preserving approach, while the control group received conventional FESS. The results demonstrated significant postoperative improvement in both groups; however, superior outcomes were observed in the main group. The modified technique was associated with greater reduction in SNOT-22 scores, lower incidence of complications such as synechiae and mucosal edema, and improved restoration of nasal function. Additionally, recurrence rates were significantly lower, and overall treatment efficacy was higher compared to the conventional surgical approach. The findings confirm that the proposed minimally invasive, function-preserving FESS technique provides better clinical outcomes, enhances mucosal recovery, and ensures more effective long-term control of CRS in pediatric patients.

Keywords: *chronic rhinosinusitis (CRS), diagnosis, conservative, surgical treatment, functional endoscopic sinus surgery (FESS), ostiomeatal complex*

INTRODUCTION

Chronic rhinosinusitis (CRS) is a persistent inflammatory condition of the nasal and paranasal sinus mucosa lasting 12 weeks or more, which significantly impairs quality of life and generates a substantial healthcare burden worldwide [1, 2]. Epidemiological studies have consistently shown that the prevalence of CRS has increased over the past decades, with recent data reporting population prevalence rates ranging from approximately 5% to 19% in different regions and demographic groups [3, 4]. This rising trend has been attributed to factors including environmental pollution, increasing allergic disease, microbial dysbiosis, and higher detection rates due to improved imaging technologies [5, 6].

CRS often coexists with comorbidities such as asthma, allergic rhinitis, and immunologic disorders, which complicates its clinical course and demands multidisciplinary approaches to management [7, 8]. The disease contributes to significant direct medical costs related to repeated physician visits, diagnostic procedures, and pharmacotherapy, as well as indirect costs from reduced productivity and absenteeism [9, 10]. Pediatric CRS in particular presents unique challenges, as symptoms overlap with other common childhood conditions, and the impact on growth, cognitive function, and school performance has been increasingly recognized [11, 12].

Despite advances in diagnostics and therapeutic modalities, a considerable proportion of patients with acute rhinosinusitis progress to a chronic form that is refractory to standard conservative treatments, including prolonged antibiotic therapy and corticosteroids, leading to persistent symptoms and frequent surgical referrals [13, 14]. Endoscopic sinus surgery has im-

proved outcomes for many patients; however, variability in surgical indications, techniques, and long-term effectiveness underscores the need for evidence-based optimization of treatment algorithms, especially in pediatric populations [15, 16].

Consequently, the problem of accurately diagnosing CRS, predicting disease progression, and selecting individualized therapeutic strategies remains highly relevant. Identification of clinical, immunological, and radiological factors that serve as reliable prognostic markers is critical for improving surgical decision-making, reducing complication rates, and enhancing long-term disease control [17–19]. Therefore, studies focusing on multifactorial diagnostic assessment and tailored surgical approaches continue to be of paramount scientific and practical importance in modern otorhinolaryngology.

Based on the above, **the purpose of this study** was to optimize the choice of method of surgical treatment of diseases of the paranasal sinuses in patients with chronic rhinosinusitis.

MATERIALS AND METHODS

We conducted surgical treatment in a cohort of 100 pediatric patients diagnosed with chronic rhinosinusitis (CRS), aged 8 to 16 years, who were consecutively admitted to the Department of Otorhinolaryngology at the “Happy Life” Medical Centre of the Ministry of Health of the Republic of Uzbekistan. The study period spanned from January 2019 to December 2025. All procedures were performed in compliance with ethical standards for research involving human subjects and with informed consent obtained from the legal guardians of each patient.

Detailed clinical information was obtained for each patient, including presenting complaints, duration and severity of symptoms, history of previous medical

therapy, history of allergic disease, and documented episodes of acute exacerbations. A comprehensive anamnesis and physical examination were conducted, with particular emphasis on sinonasal symptomatology specified in the EPOS 2020 criteria, including nasal obstruction, purulent nasal discharge, post-nasal drip, hyposmia/anosmia, facial pain/pressure, and sleep disturbance.

General physical assessment was performed by a pediatrician, and all patients underwent a standardized ear, nose, and throat (ENT) examination using both anterior rhinoscopy and nasal endoscopy. Rigid endoscopes (0°, 30°) were employed to evaluate mucosal edema, purulence in sinus ostia, nasal polyps (graded according to the Lund–Kennedy scoring system), septal deviation, inferior turbinate hypertrophy, and other structural abnormalities. Endoscopic evaluation was conducted under topical anesthesia to minimize discomfort and ensure accurate assessment of the sinonasal anatomy.

Preoperative radiological evaluation included three-dimensional (3D) computed tomography (CT) of the paranasal sinuses in all patients. CT imaging was performed with high-resolution slices in axial, coronal, and sagittal planes, allowing detailed evaluation of the osteomeatal complex, sinus pneumatization, presence of mucosal thickening, obstruction of sinus ostia, anatomical variants (e.g., Haller cells, Onodi cells, concha bullosa), and bony erosion. Radiologic severity was scored using the Lund–Mackay CT staging system, with scores ranging from 0 (no abnormality) to 24 (complete opacification of all sinus groups).

The diagnosis of chronic rhinosinusitis was established on the basis of:

1. A clinical history of symptoms lasting ≥ 12 weeks in accordance with EPOS 2020 definitions.
2. Endoscopic findings such as mucopurulent discharge or edema in the middle meatus and/or polyps.
3. Supporting CT evidence of sinonasal mucosal disease and ostiomeatal complex obstruction.

We applied the EPOS 2020 classification system to categorize CRS patterns, including CRS without nasal polyps (CRSsNP), CRS with nasal polyps (CRSwNP), and other endotypes. Allergic status was assessed by skin prick testing or specific IgE assays. Where indicated, additional immunologic tests, bacterial cultures, or allergy panels were performed to stratify patient risk and guide perioperative management.

Our treatment strategy was based on the principle that therapy should be comprehensive, patient-specific, minimally invasive where appropriate, and aligned with the latest evidence-based rhinologic surgical standards. Treatment decisions balanced the severity and chronicity of disease, previous medical therapy response, comorbidities (such as asthma or allergic rhinitis), and identified contraindications to specific medications (e.g., systemic corticosteroids).

To optimize surgical outcomes, we developed a treatment algorithm that began with maximal medical therapy in all patients, including saline irrigation, intranasal corticosteroids, and targeted antibiotics where

bacterial infection was suspected. Indications for surgery included persistent symptoms despite adequate medical management, radiologically confirmed ostiomeatal complex obstruction, recurrent acute exacerbations, and complications such as orbital or intracranial extension.

The main objective of our surgical approach was to employ techniques that provided maximal functional restoration of sinus ventilation and drainage with minimal trauma to the developing sinonasal skeleton, thereby reducing postoperative morbidity, preserving mucosal integrity, and promoting long-term disease control.

For comparative analysis, patients were stratified into two treatment groups:

Group 1 (Intervention Group) comprised 54 children with CRS who underwent a modified Functional Endoscopic Sinus Surgery (FESS) protocol. The surgical plan focused on selective removal of the inferior portion of the uncinate process to reestablish natural ostial drainage, combined with conservative enlargement of sinus ostia (maxillary, anterior ethmoid) where indicated. This technique was chosen to maintain mucosal surfaces, minimize disruption of mucociliary clearance, and preserve anatomic landmarks essential for normal sinus function.

Group 2 (Control Group) consisted of 46 children of similar age and clinical severity with CRS who received a traditional FESS approach, involving complete removal of the uncinate process and systematic enlargement of the ostiomeatal complex, with partial ethmoidectomy and maxillary antrostomy performed as deemed necessary. These procedures adhered to established rhinologic surgical standards for conventional FESS.

All surgeries were performed under general anesthesia with endotracheal intubation. Standardized operative techniques included use of high-definition endoscopes, microdebriders, suction electrocautery, and navigational guidance systems when complex anatomy was encountered. Particular attention was paid to preserving the ethmoid bulla, middle turbinate, and mucosal surfaces to support physiologic healing and reduce scar formation.

Perioperative antibiotic prophylaxis was administered according to institutional protocols. Topical decongestion and corticosteroid irrigations were initiated intraoperatively and continued postoperatively to mitigate inflammation. Postoperative care included saline nasal rinses, endoscopic debridement at regular intervals, and symptom monitoring using validated tools such as the Sinonasal Outcome Test-22 (SNOT-22) and symptom diaries. Surgical outcomes were evaluated through follow-up assessments at 1, 3, 6, and 12 months, including symptom scores, endoscopic findings (Lund–Kennedy), recurrence rates, need for revision surgery, and complication rates. Statistical analysis employed appropriate parametric and non-parametric tests, with a significance threshold set at $p < 0.05$ (Table 1).

Table1.

Assessment of symptom severity using the SNOT-22 scale

| No. | SNOT-22 Symptom Item | Mean Score (n = 100) |
|-----|---|----------------------|
| 1 | Need to blow nose | 3.8 |
| 2 | Nasal discharge (anterior/postnasal drip) | 3.6 |
| 3 | Sneezing | 3.1 |
| 4 | Nasal congestion/blockage | 4.2 |
| 5 | Loss of smell or taste | 3.7 |
| 6 | Facial pain/pressure | 3.5 |
| 7 | Ear fullness/pressure | 2.8 |
| 8 | Fatigue | 4.0 |
| 9 | Difficulty falling asleep | 3.9 |
| 10 | Waking up at night | 3.4 |
| 11 | Lack of a good night's sleep | 3.2 |
| 12 | Wake up tired | 4.1 |
| 13 | Reduced productivity | 3.6 |
| 14 | Reduced concentration | 3.3 |
| 15 | Frustrated/restless/irritable | 3.0 |
| 16 | Sadness | 2.9 |
| 17 | Shortness of breath | 3.5 |
| 18 | Sore throat | 2.6 |
| 19 | Bad breath | 2.7 |
| 20 | Thick nasal discharge | 3.8 |
| 21 | Cough | 3.0 |
| 22 | Embarrassment caused by symptoms | 2.5 |
| | Total average SNOT-22 score | 3.4 |

A total of 100 pediatric patients with chronic rhinosinusitis underwent SNOT-22 assessment before and 6 months after surgical treatment. The mean preoperative SNOT-22 score was 74.8 ± 11.4 , while the postoperative mean was 28.6 ± 9.8 , demonstrating a significant

reduction in symptom severity. The mean difference was 46.2 points, with a standard error of 1.05. Statistical analysis using a paired t-test revealed a t-value of 44.0, corresponding to a p-value < 0.0001 , indicating a highly significant improvement in patient-reported outcomes following surgery.

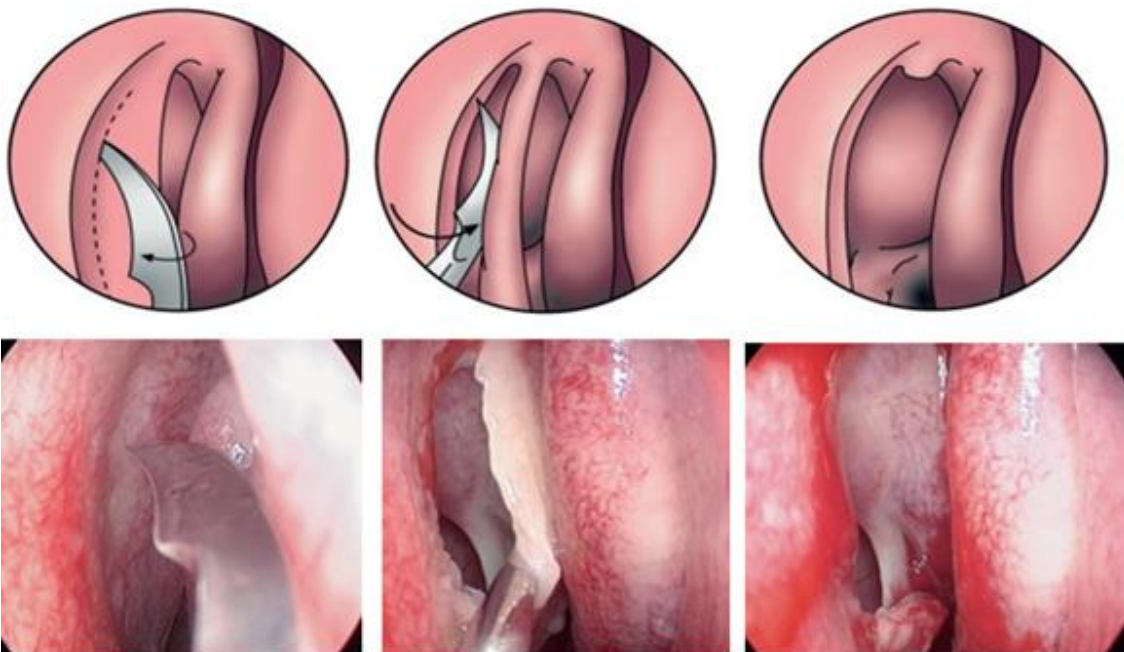


Fig. 1. Intraoperative technique used in the minimally invasive functional endoscopic sinus surgery (FESS) performed on pediatric patients with chronic rhinosinusitis

The provided image illustrates the step-by-step intraoperative technique used in the minimally invasive functional endoscopic sinus surgery (FESS) performed on pediatric patients with chronic rhinosinusitis (CRS) in our study (Fig. 1.). The sequence demonstrates both schematic representations (top row) and intraoperative endoscopic views (bottom row), corresponding to the selective resection of the lower portion of the uncinate process — a technique we adopted as part of our refined surgical approach based on EPOS 2020 recommendations and recent pediatric rhinologic surgery protocols. In our cohort of 56 patients (main group), this technique involved a targeted removal of only the inferior segment of the uncinate process, preserving the superior portion and the integrity of the natural ostiomeatal complex. This conservative modification was guided by the goal of minimizing mucosal trauma while achieving adequate access to the maxillary sinus ostium for natural drainage restoration. The initial step included medialization of the uncinate process, followed by a precise incision with a sickle knife, and subsequent partial resection using Blakesley forceps, as shown in the first two panels. The third panel illustrates the final view with preservation of the superior uncinate border and clear exposure of the maxillary ostium. Intraoperatively, no damage was observed to adjacent structures such as the lamina papyracea or middle turbinate. The surgical field remained bloodless in most cases, and mucosal preservation was achieved, reducing postoperative synechia formation and facilitating mucociliary recovery.

Postoperative endoscopic examination at follow-up revealed clear re-epithelialization of the surgical site, absence of adhesions, and patent maxillary ostia, supporting the efficacy and safety of the minimally invasive approach. This technique also allowed for faster

recovery, minimal crusting, and improved patient comfort in the early postoperative period. Compared to the control group, which underwent complete uncinectomy and more extensive ethmoidectomy, our method demonstrated fewer complications, lower recurrence rates, and better preservation of nasal physiology. The successful outcome observed in this group confirms that partial uncinectomy with functional ostium preservation represents a reliable and child-friendly surgical option for CRS, aligning with principles of mucosa-sparing endoscopic sinus surgery and contributing to long-term disease control with minimal surgical morbidity.

The proposed surgical procedure was performed under combined endotracheal general anesthesia with continuous endoscopic visualization. After adequate nasal decongestion, the middle turbinate was gently medialized toward the nasal septum to improve access to the middle meatus. Using reverse-cutting instruments and Blakesley forceps, a selective resection of the inferior portion of the uncinate process was carried out. Subsequently, the natural maxillary sinus ostium was identified and conservatively enlarged in the posterior, inferior, and anterior directions to restore physiological ventilation and drainage. Under 45° endoscopic guidance, the maxillary sinus cavity was thoroughly inspected, and pathological secretions and inflammatory tissue were carefully removed. Meticulous hemostasis was achieved at the end of the procedure. Elastic hemostatic nasal packing was placed to prevent postoperative bleeding and stabilize the surgical site and was routinely removed on the first postoperative day (Fig. 2.).

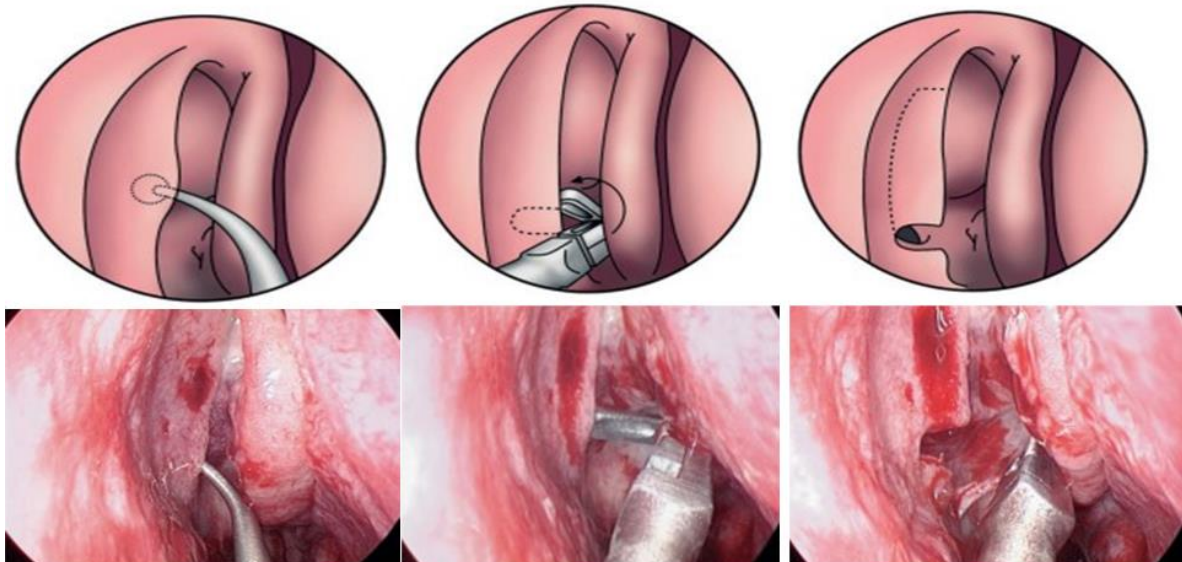


Fig. 2. Step-by-step surgical approach performed on pediatric patients with chronic rhinosinusitis

The criteria for assessing the effectiveness of CRS therapy in both groups of patients were: absence of complaints and subjective sensations, cleansing of the washing solution from the nasal cavity and SNP, reduction of hyperemia and swelling of the mucous membranes of the nasal cavity with a decrease in the size of the nasal turbinated, regression of symptoms of focal

intoxication, as well as the absence of exacerbation CRS for the entire observation period and long-term remission. To maintain the homogeneity of the groups, patients were selected taking into account the identical distribution of disease activity in all groups. At the beginning of treatment, the children were in a hospital setting, and subsequently received outpatient treatment

with follow-up after 3 and 6 months, for two years. Follow-up observation was carried out for two years.

RESULTS AND DISCUSSION

At the time of hospital admission, the majority of patients presented with pronounced sinonasal symptoms. Nasal obstruction was reported by **98 patients (98.0%)**, while **46 patients (46.0%)** demonstrated purulent discharge in the nasopharynx, and **69 patients (69.0%)** complained of mucous nasal secretion. General systemic manifestations were also frequently observed: **41 patients (41.0%)** reported generalized weakness and fatigue, **33 patients (33.0%)** experienced chronic cough, and **28 patients (28.0%)** exhibited increased irritability and emotional lability.

In patients with more advanced stages of chronic rhinosinusitis, persistent headache of varying intensity and unilateral or bilateral impairment of nasal breathing were documented. These clinical manifestations developed gradually over several months and were not associated by patients with any specific triggering factors, indicating the progressive and insidious nature of the disease.

During the postoperative follow-up period, a marked positive trend in clinical outcomes was observed in both study groups, with significantly better results in the main treatment group. Beginning from the second postoperative day, patients who underwent the modified minimally invasive surgical procedure combined with comprehensive medical therapy demonstrated a pronounced improvement in general condition. Symptoms of fatigue, weakness, and irritability regressed completely in most cases. Episodes of epistaxis ceased, and the frequency of dyspeptic manifestations, including halitosis and coated tongue, was significantly reduced compared with the control group ($p < 0.01$).

Endoscopic monitoring revealed a progressive reduction in mucosal edema, restoration of physiological ventilation of the middle meatus, and normalization of mucociliary clearance. Postoperative crust formation

and inflammatory secretion decreased substantially within the first week after surgery. By the end of the first postoperative month, stable epithelialization of the surgical field was observed in the majority of patients.

The incidence of postoperative complications, including recurrent epistaxis and formation of intranasal synechiae, was significantly lower in the main group. Adhesive processes in the middle nasal meatus were observed in only **4%** of patients in the intervention group, compared with **15%** in the control group. Similarly, persistent mucosal edema was detected in **7%** and **21%** of patients, respectively (Table 1).

Functional outcomes assessed using endoscopic scoring systems and patient-reported measures demonstrated sustained improvement during the follow-up period. Restoration of nasal breathing, reduction of nasal discharge, and alleviation of facial pressure were achieved in more than **85%** of patients in the main group. These results were consistent with the significant postoperative reduction in SNOT-22 scores observed in our cohort.

The superior clinical outcomes associated with the proposed surgical technique may be attributed to its mucosa-preserving nature, limited resection of the uncinat process, and preservation of key anatomical structures of the ostiomeatal complex. This approach minimizes postoperative scarring, reduces inflammatory remodeling, and promotes physiological sinus drainage.

Our findings support the concept that targeted, minimally invasive functional endoscopic sinus surgery, performed in accordance with EPOS 2020 recommendations, provides effective symptom control and improved quality of life in pediatric patients with chronic rhinosinusitis. The combination of conservative surgical intervention and optimized postoperative management appears to be crucial for achieving long-term disease remission and preventing recurrence.

Table 2

Local signs after surgical treatment in observed patients

| Sign | Before treatment, n=100 | | Control group, n=48, P1 | | Main group n=56, P2 | | P1:2 |
|--|-------------------------|------|-------------------------|------|---------------------|-----|--------|
| | abs | % | abs | % | abs | % | |
| Swelling of nasal cavity | 65 | 62,5 | 9 | 18,8 | 5 | 8,9 | <0,05 |
| Hyperemia of the nasal cavity | 79 | 76 | 8 | 16,7 | 4 | 7,1 | <0,05 |
| Subatrophy of the nasal cavity | 14 | 13,5 | 5 | 8,9 | 4 | 8,3 | >0,05 |
| Mucous secretions from the nasal cavity | 72 | 69,2 | 12 | 25,0 | 3 | 5,4 | <0,001 |
| Purulent discharge from the nasal cavity | 48 | 46,2 | 5 | 10,4 | 0 | 0 | <0,001 |
| Hypertrophy of the nasal turbinates | 58 | 55,8 | 14 | 29,2 | 5 | 8,9 | <0,01 |
| Polypous growths of the nasal turbinates | 8 | 7,7 | 0 | 0,0 | 0 | 0,0 | >0,05 |

Note: * - differences compared with the data of the proposed treatment are statistically significant ($P < 0.05$; $P < 0.01$; $P < 0.001$).

Immediately after surgical intervention, patients in both study groups demonstrated a significant improvement in general condition, accompanied by a reduction

in local inflammatory manifestations, decreased sinonasal discharge, improvement in olfactory function, and alleviation of facial pain. These changes progressed steadily over time, indicating favorable postoperative

recovery dynamics. Endoscopic examination of the nasal cavity and nasopharynx in the early postoperative period revealed pronounced differences between the groups. In the majority of patients in the main group, a marked reduction in inferior and middle turbinate edema was observed. The nasal mucosa appeared pale pink, well-epithelialized, and free of pathological secretions, while no inflammatory exudate was detected on the surface of the pharyngeal tonsil.

In contrast, patients who underwent conventional surgical treatment exhibited persistent signs of mucosal inflammation in a subset of cases. Complete resolution of purulent nasal discharge was achieved in all patients in the main group immediately after combined treatment ($p < 0.001$), whereas this symptom persisted in 5 patients (10.0%) in the control group. Residual mucosal hyperemia was detected in 4 patients (7.0%) following the proposed minimally invasive technique, compared with 8 patients (16.0%) after traditional surgery, demonstrating a statistically significant intergroup difference ($p < 0.05$). These findings indicate that the modified surgical approach provides more effective early postoperative control of inflammatory processes and promotes faster restoration of normal sinonasal mucosal function.

A significant reduction in nasal mucosal edema and turbinate hypertrophy was observed in both study groups following surgical intervention. However, residual hypertrophic changes remained more pronounced in the control group, being detected in 9 patients (18.8%) who underwent conventional treatment, compared to only 5 patients (8.9%) in the group that received the proposed minimally invasive technique ($p < 0.05$), indicating a statistically significant difference favoring the modified approach. While occasional episodes of mild postoperative epistaxis were noted in both groups, no cases required intervention. Subtrophic changes of the nasal mucosa were detected in 5 patients (8.9%) in the control group and 4 patients (8.3%) in the main group, without a statistically significant difference ($p > 0.05$), suggesting comparable outcomes with respect to mucosal integrity preservation. In all patients with polypoid changes, endoscopic removal was successfully performed, with favorable healing outcomes observed in both groups. Notably, patients who underwent functional endoscopic sinus surgery (FESS) using the proposed technique demonstrated superior endoscopic findings, characterized by the absence of edema and hyperemia, more rapid mucosal re-epithelialization, and accelerated wound healing, compared to those treated with the traditional approach. These results support the clinical advantages of the modified surgical method in terms of postoperative recovery, mucosal preservation, and reduction in inflammation-related complications. In the control group, endoscopic examination of the nasal cavity performed one month after traditional surgical treatment revealed persistent mucosal edema and congestion, predominantly in the upper regions of the nasal cavity. The nasal mucosa appeared more uniform in texture, with a smooth and shiny surface, and was covered by clear, serous mucus. Importantly, no recurrence of nasal polyps was observed at this stage.

At the six-month follow-up, morphological changes in the mucosa became more pronounced. While the nasal cavity remained free of polyps, there was evidence of diffuse thickening of the mucosal lining in the upper nasal regions, indicative of chronic subclinical inflammation. In contrast, the lower nasal regions demonstrated early signs of mucosal atrophy, with focal areas of thinning and dullness. The character of nasal secretions had also changed—mucus appeared more heterogeneous, and localized accumulations of dense, viscous mucus were observed in several patients, suggesting partial dysfunction of mucociliary clearance.

Despite these structural and secretory changes, the enlarged natural openings of the maxillary sinuses and the ethmoidal labyrinth cells remained widely patent and free from discharge, indicating that anatomical sinus drainage was preserved. However, the presence of atrophic zones and thickened upper mucosa suggests that traditional surgical techniques may result in region-specific healing disturbances, potentially compromising long-term mucosal function.

In the main group, endoscopic examination performed **one month after the proposed surgical intervention** revealed a **wide nasal cavity with clean, well-aerated natural ostia** of the maxillary sinuses and ethmoidal labyrinth cells. The mucosal surfaces were smooth, uniformly colored, and free of exudate. By the **six-month follow-up**, these favorable findings had further improved: the nasal mucosa across all regions displayed a near-normal pale pink coloration, with **no evidence of inflammation or discharge**, and full **restoration of nasal airflow** was observed in all patients.

Compared to the control group, patients who underwent the modified technique demonstrated **better preservation of physiological mucosal characteristics** and **faster recovery** of normal nasal function. The mucosa remained structurally intact, without evidence of atrophy or synechiae.

Long-term follow-up over a **two-year period** revealed a **more stable clinical course** in children who received the comprehensive treatment protocol, with a significantly lower rate of disease recurrence. The **mean annual relapse rate** in the main group was **1.8 ± 0.12 episodes per year**, which was **more than 1.8 times lower** than that observed in the control group (**3.4 ± 0.16 episodes per year**). In terms of overall treatment efficacy, **a positive outcome was achieved in 96.2%** of patients who received the proposed surgical approach, compared to **79.4%** in the group treated with the conventional method ($p < 0.01$).

CONCLUSION

Thus, our findings demonstrate that the **proposed selective and minimally invasive surgical technique for treating chronic rhinosinusitis in children** offers superior clinical outcomes compared to traditional surgical methods. It ensures more effective and physiologically compatible sanitation of the nasal cavity and paranasal sinuses, promotes faster mucosal recovery, reduces relapse frequency, and improves overall quality of life. These advantages support its **broad implementation in pediatric otorhinolaryngological practice** as a safe and effective treatment strategy for CRS.

References

1. Vokhidov U.N. Clinical and immunological features of chronic polypous rhinosinusitis and their treatment. Author's abstract. dis. ...doc. honey. Sci. – Tashkent, 2017. - 13-17 p.
2. Gavrilenko Yu.V. Diagnostic endoscopy of ENT organs. // Kyiv, "Dobrobut", 2014. P. 16.
3. Braun T, Betz CS, Stelter K, Leunig A. FESS and surgical training: what are the problems? *Laryngo-Rhino-Otol.* 2011; 90: 10-14.
4. Fokkens W.J., Lund V.J., Mullol J. et al. European position paper on rhinosinusitis and nasal polyps 2012. *Rhinol Suppl.* 2017; 23(3): 1-298.
5. Nguyen QA, Cua DJ, Ng M, Rice DH. Safety of endoscopic sinus surgery in a residency-training program. *Ear Nose Throat J.* 2017; 78: 898-902, 904.
6. Zuckerman JD, Wise SK, Rogers GA, Senior BA, Schlosser RJ, DelGaudio JM. The utility of cadaver dissection in endoscopic sinus surgery training courses. *Am J Rhinol Allergy* 2019; 23: 218-224.
7. Karaboeva, Z. K., Nasretdinova, M. T., Egamberdieva, Z. D., & Karabaev, H. E. (2024). Optimization of Treatment Methods for Chronic Allergic Rhinitis in Workers Producing Glass-Plastic Structures. *Central Asian Journal of Medical and Natural Science*, 5(4), 871-875.
8. Нурмухамедова, Ф. Б. (2021). АДЕНОИДНАЯ ВЕГЕТАЦИЯ У ДЕТЕЙ С АЛЛЕРГИЧЕСКИМ РИНИТОМ. *SCIENTIFIC IDEAS OF YOUNG SCIENTISTS*, 30.
9. Rajabov, A. K., & Toshtemirova, M. M. (2025). Особенности хронических риносинуситов у детей. *Eurasian Journal of Otorhinolaryngology-Head and Neck Surgery*, 4, 42-46.

Koshyrets Anna Viktorivna

4th year student

Bukovinian State Medical University

Chernivtsi, Ukraine

Kozar Oleh Mykhailovych

Assistant of the Department of Obstetrics,

Gynecology and Perinatology

Bukovinian State Medical University

Chernivtsi, Ukraine

IMMUNOLOGICAL INFERTILITY AS A COMPONENT OF THE ETIOLOGY OF INFERTILITY IN MARRIED COUPLES

Abstract.

Infertility is a significant global health problem: according to the World Health Organization, approximately one in six adults worldwide will experience reproductive dysfunction during their lifetime, representing about 15% of the population of reproductive age. In the context of immunological factors, separate data indicate that approximately 10–20% of cases of infertility in married couples may be related to immune reactions. Special attention is paid to the role of the immune system in the regulation of reproductive processes, including the mechanisms of formation of antisperm antibodies, autoimmune reactions, the involvement of cells of the immune system in implantation processes, and the influence of chronic infectious and inflammatory processes on fertility. Modern approaches to the diagnosis and treatment of immunological infertility, as well as the importance of immunological tolerance for the successful course of pregnancy, are highlighted.

Key words: *immunological infertility, immunological incompatibility, antisperm antibodies, autoimmune processes, implantation, immune system, cytokines.*

Introduction. Infertility is an important medical and social problem of modern society. According to modern estimates, approximately 10–15% of married couples of reproductive age face difficulties in conceiving a child. The causes of infertility can be diverse and include anatomical abnormalities, hormonal disorders, genetic factors, infections, as well as immunological mechanisms. In recent years, scientists have paid considerable attention to the immunological aspects of fertility disorders, since the immune system plays an important role in the regulation of reproductive processes.

Immunological factors can affect various stages of the reproductive cycle — from gamete formation to embryo implantation and pregnancy development. Violations of immune regulation can cause impossibility of fertilization, as well as repeated implantation failures or early pregnancy losses. A special role in the development of immunological infertility is played by autoimmune processes, formation of antisperm antibodies, imbalance of cells of the immune system and chronic inflammatory reactions [1]. Understanding these mechanisms is important for improving the diagnosis and treatment of infertility.

Results

The human immune system performs not only a protective function, but also actively participates in the regulation of many physiological processes, including reproductive ones. Under normal conditions, immune mechanisms ensure a balance between protecting the body from pathogens and maintaining tolerance to one's own cells and tissues. In the reproductive process, the immune system is involved in the regulation of ovulation, fertilization, embryo implantation, placenta development, and pregnancy maintenance.

During ovulation, a local inflammatory reaction occurs in the ovary, which contributes to the rupture of the follicle and the release of the egg. Cytokines, prostaglandins, macrophages and other cells of the immune system take part in this process. Violation of this mechanism can lead to anovulation or deterioration of oocyte quality. After fertilization, the embryo contains the genetic material of both the mother and the father, so it is partially foreign to the woman's body. Normal pregnancy requires immunological tolerance to the embryo, which is maintained thanks to regulatory T-lymphocytes, cytokines and other mechanisms of immune regulation.

One of the most studied mechanisms of immunological infertility is the formation of antisperm antibodies. These antibodies are synthesized in response to sperm antigens, which the immune system may perceive as foreign structures. Antisperm antibodies can be formed in both men and women [2]. In men, their formation is often associated with a violation of the blood-testicular barrier, which occurs as a result of injuries, infections, surgical interventions or varicocele [3]. In women, antibodies can be formed after contact with spermatozoa in case of immunological sensitization.

The presence of antisperm antibodies has a negative effect on various stages of fertilization, in particular, it causes agglutination of spermatozoa, reduces their mobility, prevents penetration through the cervical mucus and blocks the interaction of the spermatozoon with the egg [4]. In some cases, these antibodies can affect the early stages of embryo development.

Immunological infertility can be associated not only with antisperm antibodies, but also with autoim-

immune processes. In such cases, the immune system begins to produce antibodies against the body's own cells and tissues. These include antinuclear antibodies, antiphospholipid antibodies, antibodies to thyroid tissue, as well as antibodies to the egg cell membrane (zona pellucida) [5]. In particular, antibodies to the zona pellucida can prevent sperm from entering the egg. Such immune reactions can also disrupt the process of implantation and contribute to the development of early pregnancy losses. Autoimmune diseases, in particular systemic lupus erythematosus or antiphospholipid syndrome, are often associated with impaired reproductive function [6].

An important role in the regulation of implantation is played by cells of the immune system, in particular, natural killer cells and T-lymphocytes [7]. In the mucous membrane of the uterus, these cells constitute a significant part of the immune cells and participate in the formation of the placenta and remodeling of the endometrial vessels. Under normal conditions, they perform a regulatory function and contribute to the development of pregnancy, but their increased activity or number can lead to disruption of embryo implantation and repeated pregnancy failures.

In addition, the balance between different types of T-lymphocytes, particularly between Th1 and Th2, is important. During a normal pregnancy, the Th2 type of immune response prevails, which provides immunological tolerance to the fetus. Violation of this balance can lead to rejection of the embryo.

Chronic infectious and inflammatory processes of the reproductive system also play an important role in the development of immunological infertility [8]. Infectious agents are able to activate the immune system and cause long-term inflammation, which is accompanied by increased production of pro-inflammatory cytokines, in particular interleukin-1, interleukin-6 and tumor necrosis factor. This leads to damage to the tissues of the reproductive organs and the creation of unfavorable conditions for fertilization and implantation.

Chlamydia trachomatis, Mycoplasma hominis and Ureaplasma urealyticum are among the main causative agents of chronic infections of the reproductive tract. Long-term persistence of these microorganisms causes constant activation of the immune system and supports a chronic inflammatory process, which negatively affects the structure of the endometrium and the ability to implant.

Diagnosis of immunological infertility includes a complex of laboratory and clinical research methods [9]. It involves the determination of antisperm antibodies in blood or cervical mucus, analysis of subpopulations of lymphocytes, determination of cytokine levels, detection of autoantibodies, as well as examination for infections of the reproductive tract. An important stage is the exclusion of other causes of infertility, in particular hormonal, genetic or anatomical disorders [10].

Treatment of immunological infertility depends on the cause of immune disorders. In some cases, the treatment of infectious or inflammatory processes is effective, which contributes to the restoration of reproductive function. Immunomodulatory drugs, hormone therapy, and treatment of autoimmune diseases are also

used [11]. In difficult cases, assisted reproductive technologies are used, in particular, in vitro fertilization, which allows bypassing immunological barriers.

Conclusions. Immunological incompatibility of partners is a complex and multifactorial phenomenon that arises as a result of a violation of the interaction between the immune and reproductive systems. The main mechanisms of its development are the formation of antisperm antibodies, autoimmune processes, an imbalance of the immune response, and chronic infectious and inflammatory conditions. Timely diagnosis and a comprehensive approach to treatment can increase the effectiveness of therapy and the probability of pregnancy. Further research in the field of reproductive immunology will contribute to the improvement of diagnostic and treatment methods.

References

- Zhou, Y., Ding, X., & Wei, H. (2022). Reproductive immune microenvironment. *Journal of reproductive immunology*, 152, 103654. <https://doi.org/10.1016/j.jri.2022.103654>
- Šemeklienė, B., & Gradauskienė, B. (2025). Infertility and Auto-Antibodies: A Review. *Antibodies (Basel, Switzerland)*, 14(3), 76. <https://doi.org/10.3390/antib14030076>
- Gupta, S., Sharma, R., Agarwal, A., Boitrelle, F., Finelli, R., Farkouh, A., Saleh, R., Abdel-Meguid, T. A., Gül, M., Zilaitiene, B., Ko, E., Rambhatla, A., Zini, A., Leisegang, K., Kuroda, S., Henkel, R., Cannarella, R., Palani, A., Cho, C. L., Ho, C. C. K., ... Shah, R. (2022). Antisperm Antibody Testing: A Comprehensive Review of Its Role in the Management of Immunological Male Infertility and Results of a Global Survey of Clinical Practices. *The world journal of men's health*, 40(3), 380–398. <https://doi.org/10.5534/wjmh.210164>
- Wakimoto, Y., Chen, Y., Honda, H., & Shibahara, H. (2024). Advancements in the detection and implications of sperm-immobilizing antibodies in female infertility. *Journal of reproductive immunology*, 164, 104256. <https://doi.org/10.1016/j.jri.2024.104256>
- Tańska, K., Gietka-Czernel, M., Glinicki, P., & Kozakowski, J. (2023). Thyroid autoimmunity and its negative impact on female fertility and maternal pregnancy outcomes. *Frontiers in endocrinology*, 13, 1049665. <https://doi.org/10.3389/fendo.2022.1049665>
- Beltagy, A., Trespidi, L., Gerosa, M., Ossola, M. W., Meroni, P. L., & Chighizola, C. B. (2021). Antiphospholipid antibodies and reproductive failures. *American journal of reproductive immunology (New York, N.Y. : 1989)*, 85(4), e13258. <https://doi.org/10.1111/aji.13258>
- Wasilewska, A., Grabowska, M., Moskalik-Kierat, D., Brzoza, M., Laudański, P., & Garley, M. (2023). Immunological Aspects of Infertility-The Role of KIR Receptors and HLA-C Antigen. *Cells*, 13(1), 59. <https://doi.org/10.3390/cells13010059>
- Cao, Y., Yang, D., Cai, S., Yang, L., Yu, S., Geng, Q., Mo, M., Li, W., Wei, Y., Li, Y., Yin, T., & Diao, L. (2025). Adenomyosis-associated infertility: an update of the immunological perspective. *Reproductive biomedicine online*, 50(5), 104703. <https://doi.org/10.1016/j.rbmo.2024.104703>

9. Kicińska, A. M., Maksym, R. B., & Szewczyk, G. (2025). Immunological Causes of Infertility: Diagnostic Perspectives. *Biomolecules*, 16(1), 39. <https://doi.org/10.3390/biom16010039>

10. Mukherjee, N., Sharma, R., & Modi, D. (2023). Immune alterations in recurrent implantation failure. *American journal of reproductive immunology (New York, N.Y. : 1989)*, 89(2), e13563. <https://doi.org/10.1111/aji.13563>

11. Tavares, A. C. M., Martins, M. Y. M., de Souza, G. F., Lima, E. M., Rocha, C. A., de Souza, L. C., Simões, J. M. L., de Araújo, N. O., & Cavalcante, M. B. (2025). Immunological effects of GLP-1 analogs on female reproduction: Therapeutic perspectives for infertility and recurrent pregnancy loss. *Journal of reproductive immunology*, 169, 104538. <https://doi.org/10.1016/j.jri.2025.104538>

Pavlenko Zhasmina Heorhiivna
4th year student

Bukovinian State Medical University
Chernivtsi, Ukraine

Kozar Oleh Mykhailovych

Assistant of the Department of Obstetrics,
Gynecology and Perinatology
Bukovinian State Medical University
Chernivtsi, Ukraine

THE ROLE OF HEMOSTASIS SYSTEM GENE MUTATIONS IN THE PATHOGENESIS OF ABNORMAL UTERINE BLEEDING

Abstract.

Abnormal uterine bleeding (AUB) is one of the most common disorders of menstrual function in women. Although structural anomalies explain some cases of AUB, dysregulation of the hemostasis system is considered an important non-structural factor. Hemostasis involves a complex interplay between coagulation factors, platelet function, and fibrinolysis, and genetic variants affecting these pathways can disrupt this balance. Evidence from molecular studies suggests that mutations in genes that regulate blood clotting and fibrinolysis activity can cause excessive or prolonged menstrual bleeding. Violation of physiological mechanisms of hemostasis during menstruation due to such genetic variants can alter thrombin formation, fibrin formation, and clot stability, which contributes to the development of AUB.

Key words: abnormal uterine bleeding, hemostasis, coagulopathy, genetic variants, PALM-COEIN classification, menstrual cycle, von Willebrand's disease, molecular genetic methods.

Introduction. Abnormal uterine bleeding (AUB) is one of the most common disorders of menstrual function in women of reproductive age. According to various epidemiological estimates, from 10% to 30% of visits to gynecologists are related precisely to pathological changes in the menstrual cycle, manifested by a change in the regularity, duration or volume of bleeding [1]. AMAs not only disrupt physiological processes, but also have a significant impact on the quality of life, ability to study and work, psychological state and reproductive health of a woman. Excessive menstrual blood loss can lead to the development of iron-deficiency anemia, impaired cardiovascular function, and a decrease in the body's immune defenses. Studies show that up to 30–40% of patients with severe AUB have moderate or severe anemia, which negatively affects physical and psychoemotional health.

Results

To systematize the causes of abnormal uterine bleeding in modern clinical practice, the FIGO PALM-COEIN international classification is used, which divides etiological factors into structural and non-structural ones [2]. Structural causes (PALM) include endometrial polyps (P), adenomyosis (A), uterine leiomyoma (L), and endometrial malignancy and hyperplasia (M). Nonstructural causes (COEIN) include coagulopathies (C), ovulatory disorders (O), endometrial pathology (E), iatrogenic factors (I), and unclassified causes (N).

Although structural changes are often easily diagnosed using ultrasound and histological methods, a significant proportion of AUB cases are associated with nonstructural disorders, among which genetically determined disorders of hemostasis occupy a special place. Hemostasis is a key mechanism of menstrual

bleeding regulation [3]. It provides a balance between coagulation and fibrinolysis and allows the body to quickly stop blood loss during rejection of the functional endometrial layer. Violation of hemostasis, especially against the background of genetic mutations in genes encoding coagulation factors, platelet function or fibrinolysis regulators, can lead to excessive, prolonged or recurrent bleeding.

Von Willebrand disease (vWD) is the most common inherited coagulopathy characterized by deficiency or dysfunction of von Willebrand factor (vWF). This protein is responsible for the adhesion of platelets to the damaged vascular wall and the stabilization of factor VIII, which ensures normal hemostasis. With vWF deficiency, platelets cannot effectively form a primary platelet clot, and the coagulation cascade works less efficiently, leading to prolonged and heavy menstrual bleeding. Studies show that 13–25% of women with heavy menstrual bleeding have occult vWD, often without other clinical manifestations of coagulopathy [4].

The most frequent mutations in hemostasis genes:

- The G1691A mutation in the F5 gene makes Factor V Leiden resistant to activated protein C, which disrupts coagulation regulation. Resistance to protein C changes the formation of thrombin, which affects the stability of clots [5].

- The G20210A polymorphism in the F2 gene is associated with an increased level of prothrombin, which alters thrombin generation. Excess prothrombin can disrupt the balance between clot formation and dissolution, especially during menstruation, leading to unstable clots and increased blood loss [6].

- The enzyme methylenetetrahydrofolate reductase (MTHFR) controls the metabolism of homocysteine. C677T and A1298C polymorphisms can increase the level of homocysteine, which leads to endothelial dysfunction and local hemostasis disorders [7].

- Plasminogen Activator Inhibitor-1 (PAI-1) controls the rate of fibrinolysis. The 4G/5G polymorphism modulates the activity of this protein. The 4G/4G variant is associated with a higher level of PAI-1, which leads to a delay in fibrinolysis or, conversely, a violation of the stability of clots during menstruation [8].

Additional difficulties in the diagnosis of coagulopathy in patients with abnormal uterine bleeding are associated with the variability of laboratory parameters of the hemostasis system. Standard screening tests such as prothrombin time (PT), activated partial thromboplastin time (aPTT), and bleeding time (BT) do not always reflect the presence of coagulation disorders. In a number of cases, in particular, with mild or moderate forms of hereditary coagulopathies, these indicators may remain within the reference values, despite clinical manifestations in the form of heavy or prolonged menstrual bleeding. This situation is especially typical for patients with von Willebrand's disease or with certain genetic polymorphisms of genes of the hemostasis system. In this regard, in order to establish an accurate diagnosis, it is often necessary to carry out extended laboratory studies, including determination of the level and functional activity of the von Willebrand factor, assessment of the activity of coagulation factors, studies of platelet function, as well as molecular genetic methods of analysis aimed at identifying gene polymorphisms that regulate the processes of coagulation and fibrinolysis [9].

The use of modern molecular genetic technologies has significantly expanded the possibilities of diagnosing disorders of the hemostasis system [10]. New-generation sequencing methods allow identification of mutations in genes that regulate the processes of coagulation, platelet aggregation, and fibrinolysis. In some clinical cases, the use of whole-exome sequencing makes it possible to detect rare genetic variants that affect the balance of hemostasis and contribute to the development of heavy menstrual bleeding [11].

Conclusions. Abnormal uterine bleeding remains one of the most urgent problems of modern gynecology, significantly affecting the physical and psycho-emotional health of women. Analysis of modern research shows that disorders of the hemostasis system, in particular hereditary mutations and polymorphisms of coagulation factor genes, platelet dysfunction and von Willebrand's disease, play a significant role in the development of heavy and prolonged menstrual bleeding. Detection of such genetically determined coagulopathies is clinically important, since standard laboratory tests (PT, aPTT, bleeding time) do not always reflect the presence of hemostasis disorders. Modern molecular genetic methods, in particular exome sequencing and analysis of polymorphisms of coagulation factors, allow to accurately identify the etiological factors of AUB, which opens up opportunities for a personalized approach to diagnosis and treatment. Early

and accurate diagnosis of genetically determined disorders of hemostasis helps to optimize therapy, reduce the risk of anemia, and improve the quality of life of patients [12]. Thus, the integration of genetic research into clinical practice is a promising direction that allows for a deeper understanding of the pathogenesis of AUB, to identify potential biomarkers and to create more effective individualized treatment strategies for patients with heavy menstrual bleeding.

References

1. Kontogiannis, A., Matsas, A., Valsami, S., Livanou, M. E., Panoskaltis, T., & Christopoulos, P. (2023). Primary Hemostasis Disorders as a Cause of Heavy Menstrual Bleeding in Women of Reproductive Age. *Journal of clinical medicine*, 12(17), 5702. <https://doi.org/10.3390/jcm12175702>
2. Fedosiuk, K., Pakharenko, L., Chayka, K., Basiuha, I., & Kurtash, O. (2023). Abnormal uterine bleeding in women of reproductive age: PALM-COIN causes. *Bangladesh Journal of Medical Science*, 22(4), 809-814. <https://doi.org/10.3329/bjms.v22i4.67116>
3. Casini, A., Moussaoui, D., Crofts, V. L., Mattiello, V., Yaron, M., & Fontana, P. (2024). Saignements utérins anormaux et anomalies de l'hémostase [Abnormal uterine bleeding and hemostasis disorders]. *Revue médicale suisse*, 20(898), 2271-2275. <https://doi.org/10.53738/REVMED.2024.20.898.2271>
4. Olsson, A., Elfvinge, P., Zetterberg, E., & Myrin-Westesson, L. (2025). Prevalence and Impact of Heavy Menstrual Bleeding in Women With von Willebrand Disease Across Age Groups: A Retrospective Study. *Haemophilia : the official journal of the World Federation of Hemophilia*, 31(6), 1243-1249. <https://doi.org/10.1111/hae.70127>
5. Favaloro, E. J., Mohammed, S., Vong, R., & Pasalic, L. (2023). Laboratory Testing for Activated Protein C Resistance (APCR): An Update. *Methods in molecular biology (Clifton, N.J.)*, 2663, 203-210. https://doi.org/10.1007/978-1-0716-3175-1_11
6. Valeriani, E., Pastori, D., Astorri, G., Porfidia, A., Menichelli, D., & Pignatelli, P. (2023). Factor V Leiden, prothrombin, MTHFR, and PAI-1 gene polymorphisms in patients with arterial disease: A comprehensive systematic-review and meta-analysis. *Thrombosis research*, 230, 74-83. <https://doi.org/10.1016/j.thromres.2023.08.006>
7. Kundid, R., Kolundžić, M., Babić, I., Kereš, T., Svaguša, T., Bingulac-Popović, J., Hećimović, A., & Jukić, I. (2025). THROMBOTIC RISK EVALUATION OF TWO METHYLENETETRAHYDROFOLATE REDUCTASE MUTATIONS C677t AND A1298c IN VENOUS THROMBOEMBOLISM. *Acta clinica Croatica*, 64(2), 233-239. <https://doi.org/10.20471/acc.2025.64.02.07>
8. Morrow, G. B., & Mutch, N. J. (2023). Past, Present, and Future Perspectives of Plasminogen Activator Inhibitor 1 (PAI-1). *Seminars in thrombosis and hemostasis*, 49(3), 305-313. <https://doi.org/10.1055/s-0042-1758791>
9. Baker, R. I., Choi, P., Curry, N., Gebhart, J., Gomez, K., Henskens, Y., Heubel-Moenen, F., James,

- P., Kadir, R. A., Kouides, P., Lavin, M., Lordkipanidze, M., Lowe, G., Mumford, A., Mutch, N., Nagler, M., Othman, M., Pabinger, I., Sidonio, R., Thomas, W., ... ISTH SSC Von Willebrand Factor, Platelet Physiology, and Women's Health Issues in Thrombosis and Haemostasis (2024). Standardization of definition and management for bleeding disorder of unknown cause: communication from the SSC of the ISTH. *Journal of thrombosis and haemostasis : JTH*, 22(7), 2059–2070. <https://doi.org/10.1016/j.jtha.2024.03.005>
10. Yoon, I., Han, J. H., & Jeon, H. J. (2024). Advances in Platelet-Dysfunction Diagnostic Technologies. *Biomolecules*, 14(6), 714. <https://doi.org/10.3390/biom14060714>
11. Ross, J. E., Mohan, S., Zhang, J., Sullivan, M. J., Bury, L., Lee, K., Futchi, I., Frantz, A., McDougal, D., Perez Botero, J., Cattaneo, M., Cooper, N., Downes, K., Gresele, P., Keenan, C., Lee, A. I., Megy, K., Morange, P. E., Morgan, N. V., Schulze, H., ... Lambert, M. P. (2024). Evaluating the clinical validity of genes related to hemostasis and thrombosis using the Clinical Genome Resource gene curation framework. *Journal of thrombosis and haemostasis : JTH*, 22(3), 645–665. <https://doi.org/10.1016/j.jtha.2023.11.011>
12. Baldwin, M. K., Ahmadzia, H. K., Bartlett, D. L., Bensen-Kennedy, D., Desai, V., Haley, K. M., Herman-Hilker, S. L., Kilgore, A. M., Kulkarni, R., Lavin, M., Luckey, S., Matteson, K. A., Paulyson-Nuñez, K., Philipp, C. S., Ragosta, S., Rosen, K., Rotellini, D., & Weyand, A. C. (2023). Building the foundation for a community-generated national research blueprint for inherited bleeding disorders: research to advance the health of people with inherited bleeding disorders with the potential to menstruate. *Expert review of hematology*, 16(sup1), 71–86. <https://doi.org/10.1080/17474086.2023.2175660>

Myronyk O.V.*Associate Professor of the
Department of Infectious Diseases and Epidemiology
Bukovinian State Medical University
Chernivtsi, Ukraine***Humeniuk V.A.***5th-year student
Bukovinian State Medical University
Chernivtsi, Ukraine*

MODERN PRINCIPLES OF LYME BORRELIOSIS DIAGNOSIS

Abstract:

*Lyme disease (Lyme borreliosis) is the most common tick-borne zoonosis in Europe and North America and represents a serious public health problem. The disease is caused by spirochetes of the *Borrelia burgdorferi* complex and is characterized by multisystem involvement with diverse clinical manifestations, which significantly complicates timely diagnosis. Early and accurate identification of borreliosis is a key condition for effective treatment and prevention of chronic complications. In the early stage of the disease, clinical diagnosis plays a leading role, particularly the detection of erythema migrans, as serological tests may be negative due to lack of seroconversion. Two-tier serological testing (screening ELISA followed by confirmation with immunoblotting) remains the gold standard in later stages.*

Keywords: *Lyme disease, borreliosis, erythema migrans, diagnostics, immunoblotting*

Materials and methods: A literature review was conducted based on international articles published in scientometric databases over the past 10 years. Current information on diagnostic principles of borreliosis was analyzed.

Objective: To analyze scientific works and literature sources and determine modern principles of Lyme borreliosis diagnosis.

Relevance: Lyme disease is an infectious multi-system disease affecting primarily the skin, nervous system, cardiovascular system, and musculoskeletal system. It can occur at any age, but incidence is higher among children and middle-aged adults. The disease is widespread in the Northern Hemisphere, and infection rates continue to rise due to environmental changes and population migration. The disease can occur at any age, but the typical age distribution suggests a higher incidence among children and middle-aged adults [1].

Clinical manifestations of the disease are due to the inflammatory response of the body to the pathogen and its structural components. Spirochetes settle in the skin and lead to the development of a local inflammatory reaction, which is clinically manifested by erythema migrans. In the absence of timely treatment, the disease can progress with the development of various systemic manifestations, most often affecting the central nervous system, musculoskeletal system or cardiovascular system [2,3]. One of the most common and pathognomonic manifestations of advanced Lyme disease is the Bannwart triad, which includes lymphocytic meningitis, peripheral facial nerve palsy, and radiculitis [4]. Sometimes the symptoms of borreliosis overlap with those of other diseases, making diagnosis difficult [5].

Results and their discussion

For a reliable diagnosis of Lyme disease, except for the presence of erythema migrans, confirmation of

borrelial infection by laboratory tests is necessary. Culturing *Borrelia* spp. from skin samples from tick-bite patients allows for a definitive diagnosis, but is usually limited almost exclusively to research experiments because of the need for specialized expertise and equipment [6]. Direct detection of *B. burgdorferi* involves methods that confirm the presence of intact spirochetes or their components (DNA, proteins) in ticks, reservoir hosts, or broken skin samples. Clinical practice includes microscopy, antigen or nucleic acid detection, and culture. Microscopic detection and antigen tests are of limited diagnostic value due to the low levels of pathogen in the samples. Antigen capture tests in cerebrospinal fluid or urine have low or questionable reliability. Therefore, culture and molecular methods are the mainstays of diagnosis.

Culturing *B. burgdorferi* is the most conclusive method for confirming active infection. It uses liquid media modified from Kelly's medium, which allow efficient growth of spirochetes even from low inoculum.

Growth is dependent on the quality of key components, including bovine serum albumin and rabbit serum, which requires careful quality control. Cultures are incubated at 30–34 °C under microaerophilic conditions for up to 12 weeks. Growth is monitored by dark-field or fluorescence microscopy, and identification of *B. burgdorferi* is confirmed by monoclonal antibodies or polymerase chain reaction (PCR).

Insufficient microscopy experience may lead to false-positive results. The efficiency of isolation of *B. burgdorferi* *sensu stricto* from erythema migrans lesions is higher in the early stages of the disease, indicating rapid elimination of the spirochetes by the immune system over time [7].

If Lyme neuroborreliosis is suspected, cerebrospinal fluid should be examined for signs of

inflammation and intrathecal antibody production to *B. burgdorferi*, as determined by assaying paired serum and cerebrospinal fluid specimens obtained on the same day. Detection of intrathecal antibodies is more specific than detection of antibody reactivity in serum or cerebrospinal fluid alone.

However, elevated antibody titers may persist for several years after infection, even after successful treatment. Therefore, additional evidence of CSF inflammation, such as pleocytosis, is required to confirm active Lyme neuroborreliosis. The diagnostic sensitivity of the antibody titer is about 80% in patients with a shorter duration (<6–8 weeks) of clinical illness and almost 100% when the duration of illness is longer.

IgM antibodies to *B. burgdorferi* are important for detecting early infection, but their detection does not aid in the serodiagnosis of late lymphocytosis. In some individuals, an IgM immune response may persist for months or even years after treatment or past infection, although this phenomenon is not associated with infection caused by *B. burgdorferi*.

Diagnostic use of single IgG assays may be sufficient if highly sensitive screening tests that include the VlsE antigen are used. In this case, IgM detection does not appear to have a significant advantage over IgG testing in recognizing early Lyme disease and may actually reduce the specificity of diagnostic testing, although this may depend on the antigen mixture used in the assay [8].

A major limitation of serological testing is that IgG and even IgM antibodies to *B. burgdorferi* may persist for months or years after near-complete or complete elimination of the spirochete with antibiotics. Antibody levels decline slowly after treatment, but Western blotting, a nonquantitative test, does not change significantly in the post-antibiotic period.

Therefore, serological testing cannot be used to determine active infection or the adequacy of antibiotic therapy [6,9]. The proportion of patients with confirmed Lyme disease is higher among individuals with simultaneous IgM and IgG positivity compared with patients with isolated IgG [10].

The characteristic band spectrum, especially in the IgG immunoblot, also provides evidence for the separation of the immune response into early and late phases, so that laboratory results and clinical symptoms can be better correlated. Therefore, a narrow band spectrum with antibodies against early-phase antigens (e.g., VlsE, OspC, p41) is usually consistent with a short-term latent infection.

However, this does not indicate persistent clinical symptoms. In contrast, a broad spectrum of bands, including late-phase antigens (e.g., p100, p17/p18), corresponds well with late manifestations (e.g., Lyme arthritis, acrodermatitis chronica atrophicans). Both antibody patterns are also consistent with asymptomatic persistence of antibodies (past infection). Recurrent infections are difficult to diagnose based on serological data alone without additional clinical information and can only be detected by a proven increase in IgG antibody levels in a parallel approach or significant changes in the immunoblot band pattern in serum samples tested in parallel [8].

Conclusion: Timely diagnosis of Lyme disease is essential and requires the integration of clinical and laboratory data. Despite the development of modern research methods, serological diagnostics have limitations, especially in the early stages of infection. Further research should be aimed at developing more sensitive and specific tests, standardizing diagnostic algorithms, and implementing a personalized approach to the evaluation of patients with suspected Lyme disease.

References

1. Arvikar SL, Steere AC. Lyme Arthritis. *Infect Dis Clin North Am.* 2022 Sep;36(3):563-577. doi: 10.1016/j.idc.2022.03.006. PMID: 36116835; PMCID: PMC9533683.
2. Radolf JD, Strle K, Lemieux JE, Strle F. Lyme Disease in Humans. *Curr Issues Mol Biol.* 2021;42:333-384. doi: 10.21775/cimb.042.333. Epub 2021 Dec 11. PMID: 33303701; PMCID: PMC7946767.
3. Donta ST. What We Know and Don't Know About Lyme Disease. *Front Public Health.* 2022 Jan 21;9:819541. doi: 10.3389/fpubh.2021.819541. PMID: 35127630; PMCID: PMC8813852.
4. Hudasch D, Konen FF, Möhn N, Grote-Levi L, Wurster U, Welte G, Conzen J, Mahmoudi N, Skripuletz T, Schwenkenbecher P. Neuroborreliosis with encephalitis: a broad spectrum of clinical manifestations. *BMC Infect Dis.* 2025 Feb 7;25(1):182. doi: 10.1186/s12879-025-10588-0. PMID: 39920572; PMCID: PMC11806785.
5. Ali G, Anwar M, Nauman M, Faheem M, Rashid J. Lyme rashes disease classification using deep feature fusion technique. *Skin Res Technol.* 2023 Nov;29(11):e13519. doi: 10.1111/srt.13519. PMID: 38009027; PMCID: PMC10628356.
6. Steere AC, Strle F, Wormser GP, Hu LT, Branda JA, Hovius JW, Li X, Mead PS. Lyme borreliosis. *Nat Rev Dis Primers.* 2016 Dec 15;2:16090. doi: 10.1038/nrdp.2016.90. Erratum in: *Nat Rev Dis Primers.* 2017 Aug 03;3:17062. doi: 10.1038/nrdp.2017.62. PMID: 27976670; PMCID: PMC5539539.
7. Aguero-Rosenfeld ME, Wang G, Schwartz I, Wormser GP. Diagnosis of Lyme borreliosis. *Clin Microbiol Rev.* 2005 Jul;18(3):484-509. doi: 10.1128/CMR.18.3.484-509.2005. PMID: 16020686; PMCID: PMC1195970.
8. Dessau RB, van Dam AP, Fingerle V, Gray J, Hovius JW, Hunfeld KP, Jaulhac B, Kahl O, Kristoferitsch W, Lindgren PE, Markowicz M, Mavin S, Ornstein K, Rupprecht T, Stanek G, Strle F. To test or not to test? Laboratory support for the diagnosis of Lyme borreliosis: a position paper of ESGBOR, the ESCMID study group for Lyme borreliosis. *Clin Microbiol Infect.* 2018 Feb;24(2):118-124. doi: 10.1016/j.cmi.2017.08.025. Epub 2017 Sep 5. PMID: 28887186.
9. Branda JA, Steere AC. Laboratory Diagnosis of Lyme Borreliosis. *Clin Microbiol Rev.* 2021 Jan 27;34(2):e00018-19. doi: 10.1128/CMR.00018-19. PMID: 33504503; PMCID: PMC7849240.
10. Hillerdal H, Henningsson AJ. Serodiagnosis of Lyme borreliosis-is IgM in serum more harmful than

helpful? Eur J Clin Microbiol Infect Dis. 2021 04093-2. Epub 2021 Jan 7. PMID: 33409833; PMCID: Jun;40(6):1161-1168. doi: 10.1007/s10096-020- PMC8139919.

Іванова Л.А.
професор кафедри педіатрії та дитячих інфекційних хвороб
Амаріца Е.Г.
Довгополюк М.В.
Студенти 6 курсу
Буковинський державний медичний університет
м. Чернівці, Україна

КЛІНІКО-ДІАГНОСТИЧНІ АСПЕКТИ ГРИБКОВИХ ІНФЕКЦІЙ (ОГЛЯД ЛІТЕРАТУРИ)

Ivanova L. A.,
Professor of the Department of Pediatrics and Pediatric Infectious Diseases.
Amarytsa E. G.
Dovgopolyuk M. V.
6th-year students.
Bukovyna State Medical University,
Chernivtsi, Ukraine.

CLINICAL AND DIAGNOSTIC ASPECTS OF FUNGAL INFECTIONS (LITERATURE REVIEW)

Анотація:

У статті проаналізовано клінічні особливості грибкових інфекцій (ГІ) у дітей. Розглянуто симптоматику поверхневих мікозів (дерматофітії, кандидози) та тяжкий перебіг інвазивних форм у групах високого ризику. Наголошено на важливості переходу від тривалих традиційних методів діагностики до сучасних молекулярних систем (ПЛР, антигенні тести) для швидкої ідентифікації збудника та зниження показників смертності.

Abstract:

The article analyzes the clinical features of fungal infections in children. It covers the symptoms of superficial mycoses and the severe course of invasive forms in high-risk groups. The study emphasizes the shift from time-consuming traditional diagnostics to modern molecular systems (PCR, antigen assays) for rapid pathogen identification and reduced mortality.

Ключові слова: *грибкові інфекції, педіатрія, дерматомікози, інвазивний кандидоз, аспергільоз, ПЛР-діагностика.*

Keywords: *fungal infections, pediatrics, dermatomycosis, invasive candidiasis, aspergillosis, PCR diagnostics.*

Матеріали та методи: нами проведений огляд літератури на основі статей, опублікованих у базах даних PubMed за останні 10 років. Аналізувалась актуальна інформація щодо клініко-діагностичних особливостей грибкових інфекцій у дітей.

Метою нашої роботи було узагальнення даних щодо клініко-діагностичних особливостей грибкових інфекцій у дітей, а також визначення найбільш інформативних методів її діагностики.

Актуальність: Грибкові інфекції (ГІ) широко поширені у всьому світі, вражаючи як дітей з ослабленим імунітетом, так і дітей з нормальним імунітетом, при цьому клінічні наслідки варіюються залежно від віку та супутніх захворювань. У дітей з ослабленим імунітетом, особливо у дітей з гематологічними онкологічними захворюваннями, ГІ призводять до значного збільшення тривалості перебування в лікарні та підвищення внутрішньолікарняної смертності, при цьому сполучені показники становлять від 15% до 20% [1]. Незважаючи на те, що поверхневі мікози (дерматофітії, кандидоз слизових оболонок) є поширеними і здебільшого легко піддаються лікуванню, найбільшу загрозу станов-

лять інвазивні грибкові інфекції (ІГІ). Частота інвазивного кандидозу вища у дітей, ніж у дорослих, і особливо висока у новонароджених. Основними факторами ризику є прийом кількох антибіотиків, глюкокортикоїдів, центральні венозні катетери, парентеральне харчування, імунодепресія, низька вага при народженні, колонізація грибами та некротизуючий ентероколіт. [2,3]. Тому рання діагностика та своєчасне протигрибкове лікування мають вирішальне значення, але є складним завданням через нечіткі клінічні прояви, тому точна ідентифікація збудника необхідна для вибору відповідного лікування [4].

Результати та їх обговорення:

Поверхневі грибкові інфекції викликаються в основному дерматофітами (наприклад, *Trichophyton*, *Microsporum*) та дріжджами (*Candida*). У немовлят переважають кандидозні інфекції, такі як пелюшковий дерматит і кандидоз ротової порожнини, у той час як у підлітків частіше розвиваються стригучий лишай стоп та тіла, оніхомікоз [6].

Стригучий лишай волосистої частини голови може проявлятися у різних формах. Фавус -

найбільш важка форма, що призводить до утворення рубців та незворотної втрати волосся. Трихофітичний тип характеризується численними дрібними осередками випадання волосся та інвазією ендотриксу (грибок усередині волосся), тоді як мікроспоричний тип проявляється більшими осередками та інвазією ектотриксу (грибок на зовнішній поверхні волосся). І остання форма, керіон — запальна, що характеризується пустулярним фолікулітом у локалізованій ділянці шкіри голови. Це важкий дерматоз, що характеризується інтенсивним запаленням, що проявляється хворобливими, червоними та набряклими ураженнями шкіри, які призводять до пошкодження волоссяних фолікулів і часто викликають рубцеве випадання волосся [6].

Щодо інфекцій шкіри та нігтів, причиною є *T. rubrum*. Грибок проявляється у вигляді сухих, кільцеподібних, лускатих уражень шкіри, що зачіпають стопи (*tinea pedis*), тулуб (*tinea corporis*), пахвинну область (*tinea cruris*) та нігті (оніхомікоз). Ці прояви, як правило, мають відносно легкий перебіг і розвиваються повільно [6].

Кандидоз - поширена грибкова інфекція у дітей, яка часто колонізує шкіру та слизові оболонки навіть у здорових людей. Пелюшковий кандидоз зазвичай проявляється почервонінням, набряком, мацерацією та сателітними пустулами, обмеженими областю підгузника, але може поширюватися і утворювати виразки та ерозії, що викликають дискомфорт, біль та свербіж. Кандидоз порожнини рота - виникає гостро або хронічно, зазвичай у вигляді болісних, еритематозних або білих псевдомембранозних уражень слизової оболонки, які можуть поширюватися на горло [6].

Традиційний підхід до діагностики дерматофітозів в основному ґрунтується на прямому мікроскопічному дослідженні (ПМІ) клінічного матеріалу, культуральному дослідженні грибів та морфологічній ідентифікації виділених патогенів. При використанні культурального методу (посів), культивування грибів займає багато часу (1–5 тижнів) що затримує діагностику. В останні роки набув популярності метод використання лампи Вуда, завдяки своїй доступності та простоті використання, особливо в закладах первинної медичної допомоги та педіатричних клініках [6].

Методи, засновані на полімеразній ланцюговій реакції (ПЛР), все частіше використовуються в діагностиці дерматофітозів завдяки їхній чудовій чутливості, специфічності та швидкому отриманню результатів у порівнянні з традиційними методами [6].

В окремих випадках поверхневі інфекції можуть викликати інвазивні інфекції, поширеність яких зростає, частково через збільшення числа груп ризику [10].

Інвазивні грибкові захворювання (ІГЗ) мають високу частоту виникнення у дітей з гематологічними злоякісними новоутвореннями та після трансплантації гемопоетичних стовбурових клітин, що значно підвищує показники смертності. До основних збудників відносяться *Aspergillus*, *Candida*

та нові неаспергільозні плісняві гриби. Інвазивний кандидоз зазвичай проявляється у вигляді кандидемії або гепатоспленомегалії, тоді як інвазивний аспергільоз переважно вражає нижні дихальні шляхи і викликає бронхіт та пневмонію аспергільозної етіології, за якими слідує інфекція носа та центральної нервової системи (ЦНС). До поширених симптомів респіраторних аспергільозних інфекцій відносяться кашель і задишка, коричнево-чорні слизові пробки та відкашлювання крові у тяжких випадках. Аспергільозні інфекції ЦНС можуть виявлятися незвичайними головними болями, судомами та тяжкою втратою свідомості. [5,9].

Традиційна мікробіологія та гістопатологія при інвазивних грибкових інфекціях мають свої обмеження. Враховуючи це, робилися спроби розробки нових методів підвищення ефективності діагностики. Останнім часом основна увага приділяється некультуральним методам виявлення антигенів та молекулярним методам. Розширено використання методів виявлення антигенів ІГЗ за допомогою аналізу 1,3- β -D-глюкану та галактоманнану, за яким послідувала розробка експрес-тестів та їх поєднання з іншими діагностичними методами для подальшого підвищення ефективності діагностики. В галузі молекулярної діагностики з'явилися ініціативи щодо стандартизації методів полімеразної ланцюгової реакції для виявлення грибів та стійкості до протигрибкових препаратів, нові платформи, такі як T2Candida Biosystems, та дослідження в галузі грибкової метаболоміки [7,8].

Висновок: Грибкові інфекції у дітей характеризуються значним клінічним поліморфізмом — від поширених поверхневих дерматофітозів до тяжких інвазивних форм із високою летальністю у групах ризику (новонароджені, пацієнти з імунодефіцитами, онкогематологічними захворюваннями). Через неспецифічність клінічних проявів рання діагностика залишається складною та потребує комплексного підходу. Сучасні методи лабораторної діагностики, зокрема молекулярно-генетичні (ПЛР) та тести на грибкові антигени (галактоманнан, β -D-глюкан), значно підвищують швидкість і точність ідентифікації збудника. Використання сучасних діагностичних технологій сприяє ранньому призначенню раціональної протигрибкової терапії, що покращує прогноз захворювання, знижує ризик ускладнень та летальних наслідків у дітей.

Список літератури:

1. Lorenzo Chiusaroli , Claudia Cozzolino , Silvia Cocchio , Mario Saia , Carlo Giaquinto , Daniele Donà , Vincenzo Baldo. Epidemiological Analysis of Fungal Infection Disease in Pediatric Population: Focus on Hospitalization from 2007 to 2022 in Veneto Region in Italy. 2025 Jan 18;14(1):93. doi: 10.3390/pathogens14010093. PMID: 39861054 PMCID: PMC11768092 DOI: 10.3390/pathogens14010093
2. Monica Chamorro , Steven A House , Blessy George . Fungal Infections. Prim Care. 2025 Sep; 52(3):487-498. doi: 10.1016/j.pop.2025.05.002. Epub 2025 Jul 7. PMID: 40835286 DOI: 10.1016/j.pop.2025.05.002

3. Niki Dermitzaki , Maria Baltogianni , Efrosini Tsekoura , Vasileios Giapros. Invasive Candida Infections in Neonatal Intensive Care Units: Risk Factors and New Insights in Prevention. *Pathogens*. 2024 Aug 6;13(8):660. doi: 10.3390/pathogens13080660. PMID: 39204260 PMCID: PMC11356907 DOI: 10.3390/pathogens13080660
4. Lucy Eletel , Talia Thomas , Emily A Berry , Gregory L Kearns. Emerging Treatments in Neonatal Fungal Infections: Progress and Prospects. *Paediatr Drugs*. 2025 Jul;27(4):449- 463. doi: 10.1007/s40272-025-00688-4. Epub 2025 Mar 21. PMID: 40117020 DOI: 10.1007/s40272-025-00688-4
5. Mingxin He , Feng Chen, Xiaomin Xian, Zhi Guo. Diagnosis and treatment of invasive fungal disease in children with hematological malignancies after chemotherapy: Challenges and strategies (Review). 2025 Nov 14;31(1):21. doi: 10.3892/etm.2025.13016 PMCID: PMC12683645 PMID: 41367710
6. Katarzyna Rychlik , Julia Sternicka-Rohde , Roman J Nowicki, Leszek Bieniaszewski , Dorota Purzycka-Bohdan. Superficial Fungal Infections in Children—What Do We Know?. 2025 Oct 18;14(20):7380. doi: 10.3390/jcm14207380 PMCID: PMC12565486 PMID: 41156250
7. Gabriel Yan , Ka Lip Chew , Louis Yi Ann Chai. Update on Non-Culture-Based Diagnostics for Invasive Fungal Disease. 2021 Oct;186(5):575-582. doi: 10.1007/s11046-021-00549-x. Epub 2021 Jul 2. PMID: 34213735 DOI: 10.1007/s11046-021-00549-x
8. Thomas J Walsh , Aspasia Katragkou , Tempe Chen , Christine M Salvatore , Emmanuel Roilides. Invasive Candidiasis in Infants and Children: Recent Advances in Epidemiology, Diagnosis, and Treatment. *J Fungi (Basel)*. 2019 Jan 24;5(1):11. doi: 10.3390/jof5010011. PMID: 30678324 PMCID: PMC6463055 DOI: 10.3390/jof5010011
9. Kam Lun Ellis Hon , Vivian PY Chan , Alexander KC Leung , Karen Ka Yan Leung , Wun Fung Hui. Invasive fungal infections in critically ill children: epidemiology, risk factors and antifungal drugs. 2024 Jun 17;13:2023-9-2. doi: 10.7573/dic.2023-9-2. PMCID: PMC11195526 PMID: 38915918
10. Noor Ul Islam, Muhammad Ikram , Muhammad Zahoor , Riaz Ullah. A comprehensive review on superficial mycoses, classification, conventional/new therapeutic approaches and fungal-drug resistance. *J Basic Clin Physiol Pharmacol*. 2025 Aug 4;36(5):319-329. doi: 10.1515/jbcpp-2024-0010. eCollection 2025 Sep 1. PMID: 40743748 DOI: 10.1515/jbcpp2024-0010

Іванова Л.А.
професор кафедри педіатрії та дитячих інфекційних хвороб
Герасімова Є.С.
Ігнат'єва А.С.
Ткач Ю.І.
Студенти 6 курсу
Буковинський державний медичний університет
м. Чернівці, Україна

**КЛІНІКО-ДІАГНОСТИЧНІ АСПЕКТИ ВРОДЖЕНОЇ ТА НАБУТОЇ ЦИТОМЕГАЛОВІРУСНОЇ
ІНФЕКЦІЇ
(ОГЛЯД ЛІТЕРАТУРИ)**

Ivanova L. A.,
Professor of the Department of Pediatrics and Pediatric Infectious Diseases.
Herasymova Ye. S.
Ihnatiyeva A. S.
Tkach Yu. I.
6th-year students.
Bukovyna State Medical University,
Chernivtsi, Ukraine.

**CLINICAL AND DIAGNOSTIC ASPECTS OF CONGENITAL AND ACQUIRED
CYTOMEGALOVIRUS INFECTION
(LITERATURE REVIEW)**

Анотація:

Цитомегаловірусна інфекція є поширеною вірусною інфекцією, що становить значну медико-соціальну проблему, особливо у вагітних жінок, новонароджених та пацієнтів з імунodefіцитними станами. Вроджена та набута форми цитомегаловірусної інфекції відрізняються за механізмами передачі, клінічним перебігом та наслідками, що обумовлює необхідність їх чіткого розмежування та своєчасної діагностики. Вроджена цитомегаловірусна інфекція виникає внаслідок внутрішньоутробного інфікування плода та може проявлятися широким спектром клінічних симптомів: від безсимптомного перебігу до тяжких генералізованих форм. Найбільш характерними проявами є затримка внутрішньоутробного розвитку, мікроцефалія, гепатоспленомегалія, жовтяниця, тромбоцитопенія та хоріоретиніт. Важливим є те, що навіть при безсимптомному перебігу у неонатальному періоді можливий розвиток віддалених ускладнень, зокрема сенсоневральної приглухуватості та затримки психомоторного розвитку.

Набута цитомегаловірусна інфекція зазвичай перебігає безсимптомно або з такими симптомами як лихоманка, втома та головний біль. Діагностика цитомегаловірусної інфекції базується на комплексному підході, що включає проведення серологічних методів, а також молекулярно-біологічних методів насамперед полімеразної ланцюгової реакції для виявлення ДНК вірусу в біологічних рідинах.

Abstract:

Cytomegalovirus infection is a common viral infection that constitutes a significant medical and social problem, especially in pregnant women, newborns and patients with immunodeficiency states. Congenital and acquired forms of cytomegalovirus infection differ in transmission mechanisms, clinical course and consequences, which necessitates their clear differentiation and timely diagnosis. Congenital cytomegalovirus infection occurs as a result of intrauterine infection of the fetus and can manifest a wide range of clinical symptoms: from asymptomatic to severe generalized forms. The most characteristic manifestations are intrauterine growth retardation, microcephaly, hepatosplenomegaly, jaundice, thrombocytopenia and chorioretinitis. It is important that even with asymptomatic course in the neonatal period, the development of long-term complications is possible, in particular sensorineural hearing loss and psychomotor developmental delay. Acquired cytomegalovirus infection is usually asymptomatic or with symptoms such as fever, fatigue and headache. Diagnosis of cytomegalovirus infection is based on a comprehensive approach, which includes serological methods, as well as molecular biological methods, primarily polymerase chain reaction for the detection of viral DNA in biological fluids.

Ключові слова: цитомегаловірус, вроджена інфекція, новонароджені, набута інфекція, діагностика, симптоми

Keywords: cytomegalovirus, congenital infection, newborns, acquired infection, diagnostics, symptoms

Матеріали та методи: нами проведений огляд літератури на основі статей, опублікованих у базах даних PubMed за останні 10 років. Аналізувалась актуальна інформація щодо клініко-діагностичних особливостей вродженої та набутої цитомегаловірусної інфекції.

Метою нашої роботи було узагальнення сучасних даних щодо клініко-діагностичних особливостей вродженої та набутої цитомегаловірусної інфекції, а також визначення найбільш інформативних методів її діагностики.

Актуальність: Цитомегаловірус людини (ЦМВ), що належить до родини нейротропних бета-герпесвірусів, може інфікувати майже всі типи клітин, включаючи епітеліальні клітини сітківки, фібробласти дерми, моноцити/макрофаги, гладком'язові клітини, нейрцити та клітини трофобласту [1]. ЦМВ передається через прямий або непрямий контакт з біологічними рідинами, такими як кров, сеча, слина, вагінальні виділення, сперма, грудне молоко, а також трансплантовані органи [2]. Людина є єдиним носієм людського ЦМВ, який є особливо специфічним для кожного виду, але може викликати тривалі неврологічні ускладнення у 10–15% безсимптомних ЦМВ-інфекцій у людей [1].

Отже, ЦМВ-інфекція - це широко розповсюджена вірусна інфекція, яка вражає приблизно 40–80% населення світу. Не зважаючи на таку високу поширеність, у більшості випадків ЦМВ-інфекція перебігає безсимптомно завдяки ефективній імунній відповіді організму [3,4].

Результати та їх обговорення: ЦМВ-інфекція може бути вродженою, тобто інфікування відбувається внутрішньоутробно та набутої - при інфікуванні після народження. Важливим є те, що вроджена ЦМВ-інфекція вважається провідною вірусною причиною внутрішньоутробної загибелі плода та викиднів [4-6]. У випадку вродженої ЦМВ-інфекції передача вірусу від матері до плода відбувається через інфікування гладком'язових клітин матки та клітин децидуальної оболонки, а також через взаємодію вірусу з рецепторами клітин трофобласта, що забезпечує його трансплацентарне проникнення [3]. Передається вроджена ЦМВ-інфекція від матері до дитини під час первинної ЦМВ-інфекції матері з частотою близько 30% протягом першого триместру вагітності, зростаючи понад 70% у третьому триместрі. В той же час, досліджено, що ризик виникнення ускладнень для здоров'я плода є найвищим при інфікуванні плода в прекоцепційному періоді [2], де ймовірність передачі інфекції оцінюється приблизно до 10%, тоді як у периконцепційному - до 30% [7]. До можливих клінічних проявів вродженої ЦМВ-інфекції належать петехії, жовтяниця, ураження печінки, хоріоретиніт, мікроцефалія, затримка внутрішньоутробного розвитку та гепатоспленомегалія. Окрім цього, можуть спостерігатися як ранні, так і віддалені ускладнення, зокрема сенсоневральна приглухуватість і порушення нейророзвитку [3,8]. Сенсоневральна втрата слуху є найчастішим довгостроковим наслідком у вродженою ЦМВ-інфекції у немовлят з поширеністю до 15% [9].

Набута ЦМВ-інфекція часто протікає безсимптомно або з незначними неспецифічними симптомами такими як лихоманка, втома та головний біль. Також часто можуть проявлятися симптоми подібні до гепатиту: нудота, блювання, біль у животі, темна сеча, біль у суглобах та жовтяниця [6]. Звичайно, латентна інфекція без будь-яких симптомів є більш поширеною ситуацією. ЦМВ залишається довільним вірусом в організмі людини і може реактивуватися в будь-який час, спричиняючи значну захворюваність [10].

При набутій ЦМВ-інфекції вірус проникає в організм через епітелій слизових оболонок. Після проникнення в організм вірус спричиняє первинне ураження таких органів, як печінка, селезінка та легені. Інтенсивне розмноження вірусу в клітинах, зокрема у фібробластах, гепатоцитах і гладких м'язових клітинах, забезпечує високе вірусне навантаження в цих органах [3].

Для діагностики вродженої ЦМВ-інфекції застосовують визначення антитіл IgG та IgM до ЦМВ у вагітної. Якщо виявляються IgM, додатково оцінюють авідність IgG до ЦМВ. У випадку, коли IgG позитивні, а IgM негативні, подальше обстеження, як правило, не проводиться через низьку ймовірність нещодавнього або активного інфікування.

Авідність антитіл - це показник міцності зв'язку антитіла з антигеном. Визначення авідності IgG дає змогу оцінити міцність зв'язку антитілу організму із ЦМВ: низька авідність вказує на недавнє або поточне зараження, тоді як висока на перенесену раніше інфекцію. Авідність антитілу при ЦМВ інтерпретується так: при значеннях 30–40% визначають низьку авідність, що свідчить про первинну ЦМВ-інфекцію, зазвичай у межах останніх 3 місяців; показники 40–60% розцінюють як проміжні, тому в такому випадку рекомендується повторити аналіз через 2–3 тижні; якщо ж авідність перевищує 60%, це відповідає високій авідності і вказує на те, що інфекція була перенесена раніше (понад 3–4 місяці тому).

Попри те, що більшість клінічних рекомендацій розглядають відсутність IgM у вагітної як ознаку відсутності недавньої чи активної ЦМВ-інфекції, а отже, і низького ризику вродженої ЦМВ-інфекції плода [11]. Натомість "золотим стандартом" для діагностики внутрішньоутробного інфікування ЦМВ є виявлення ДНК ЦМВ в амніотичній рідині методом полімеразної ланцюгової реакції (ПЛР).

Набута ЦМВ-інфекція також може діагностуватись за допомогою ПЛР та визначення специфічних антитіл класів IgM та IgG. Виявлення IgM може свідчити про первинну інфекцію або реактивацію, однак цей показник має обмежену специфічність через можливі хибнопозитивні результати та тривалу персистенцію антитіл. Визначення IgG дозволяє встановити факт інфікування в минулому, а оцінка авідності IgG може допомогти диференціювати недавню первинну інфекцію від давнього інфікування [12].

Висновок: Вроджена та набута форми ЦМВ-інфекції мають суттєві відмінності у патогенезі, клінічному перебігу та діагностичних методах, що визначає необхідність їх чіткої диференціації. Встановлено, що вроджена ЦМВ-інфекція часто супроводжується ураженням центральної нервової системи та високим ризиком віддалених наслідків. Набута ЦМВ-інфекція зазвичай супроводжується легкими симптомами такими як втома, головний біль та лихоманка. Методи діагностики як вродженої та набутої ЦМВ-інфекції характеризуються проведенням ПЛР та визначення антитіл проти ЦМВ.

Список літератури:

1. Hassan ZR, Zekry KM, Heikal EA, Ibrahim HF, Khirala SK, Abd El-Hamid SM, Amin DR, Seliem N, El-Aal GNA, Alkherkhis MM, Elhamid SAA, Mahgoub EA, Hefny MEN, El Nady GH, Badr MS. Toxoplasmosis and cytomegalovirus infection and their role in Egyptian autistic children. *Parasitol Res.* 2023 May;122(5):1177-1187. doi: 10.1007/s00436-023-07818-2. Epub 2023 Mar 14. PMID: 36917369; PMCID: PMC10097734.
2. Rybak-Krzyszowska M, Górecka J, Huras H, Massalska-Wolska M, Staśkiewicz M, Gach A, Kondracka A, Staniczek J, Górczewski W, Borowski D, Jaczyńska R, Grzesiak M, Krzeszowski W. Cytomegalovirus Infection in Pregnancy Prevention and Treatment Options: A Systematic Review and Meta-Analysis. *Viruses.* 2023 Oct 24;15(11):2142. doi: 10.3390/v15112142. PMID: 38005820; PMCID: PMC10675417.
3. Krstanović F, Britt WJ, Jonjić S, Brizić I. Cytomegalovirus Infection and Inflammation in Developing Brain. *Viruses.* 2021 Jun 4;13(6):1078. doi: 10.3390/v13061078. PMID: 34200083; PMCID: PMC8227981.
4. Marsico C, Kimberlin DW. Congenital Cytomegalovirus infection: advances and challenges in diagnosis, prevention and treatment. *Ital J Pediatr.* 2017 Apr 17;43(1):38. doi: 10.1186/s13052-017-0358-8. PMID: 28416012; PMCID: PMC5393008.
5. Pesch MH, Saunders NA, Abdelnabi S. Cytomegalovirus Infection in Pregnancy: Prevention, Presentation, Management and Neonatal Outcomes. *J Midwifery Womens Health.* 2021 May;66(3):397-402. doi: 10.1111/jmwh.13228. Epub 2021 May 24. PMID: 34031974.

Поширеність вродженої ЦМВ-інфекції у світі оцінюється до приблизно 2%.

6. Leber AL. Maternal and congenital human cytomegalovirus infection: laboratory testing for detection and diagnosis. *J Clin Microbiol.* 2024 Apr 10;62(4):e0031323. doi: 10.1128/jcm.00313-23. Epub 2024 Feb 23. Erratum in: *J Clin Microbiol.* 2024 Sep 11;62(9):e0116424. doi: 10.1128/jcm.01164-24. PMID: 38391188; PMCID: PMC11005381.

7. Nigro G, Muselli M, On Behalf Of The Congenital Cytomegalic Disease Collaborating Group. Prevention of Congenital Cytomegalovirus Infection: Review and Case Series of Valaciclovir versus Hyperimmune Globulin Therapy. *Viruses.* 2023 Jun 15;15(6):1376. doi: 10.3390/v15061376. PMID: 37376675; PMCID: PMC10302477.

8. Hadar E, Dorfman E, Bardin R, Gabbay-Benziv R, Amir J, Pardo J. Symptomatic congenital cytomegalovirus disease following non-primary maternal infection: a retrospective cohort study. *BMC Infect Dis.* 2017 Jan 5;17(1):31. doi: 10.1186/s12879-016-2161-3. PMID: 28056855; PMCID: PMC5217428.

9. Britt WJ. Congenital Human Cytomegalovirus Infection and the Enigma of Maternal Immunity. *J Virol.* 2017 Jul 12;91(15):e02392-16. doi: 10.1128/JVI.02392-16. PMID: 28490582; PMCID: PMC5512250.

10. Bai B, Wang X, Chen E, Zhu H. Human cytomegalovirus infection and colorectal cancer risk: a meta-analysis. *Oncotarget.* 2016 Nov 22;7(47):76735-76742. doi: 10.18632/oncotarget.12523. PMID: 27732934; PMCID: PMC5363545.

11. Chan ES, Suchet I, Somerset D, de Koning L, Chadha R, Soliman N, Kuret V, Yu W, Lauzon J, Thomas MA, Poon E, Zhou HY. Maternal Cytomegalovirus (CMV) Serology: The Diagnostic Limitations of CMV IgM and IgG Avidity in Detecting Congenital CMV Infection. *Pediatr Dev Pathol.* 2024 Nov-Dec;27(6):530-544. doi: 10.1177/10935266241253477. Epub 2024 Sep 13. PMID: 39270128; PMCID: PMC11568646.

12. Miyazaki D, Shimizu D, Shimizu Y, Inoue Y, Inoue T, Higaki S, Ueta M, Sugita S; Real-time PCR for ocular cytomegalovirus infection study group. Diagnostic efficacy of real-time PCR for ocular cytomegalovirus infections. *Graefes Arch Clin Exp Ophthalmol.* 2018 Dec;256(12):2413-2420. doi: 10.1007/s00417-018-4111-9. Epub 2018 Aug 27. PMID: 30151602; PMCID: PMC6224019.

Андрущак Маргарита Олександрівна
к.мед.н., доцент кафедри
інфекційних хвороб та епідеміології
Буковинський державний медичний університет
м. Чернівці, Україна
Колодницька Надія Олексіївна
здобувачка вищої медичної освіти, 5 курс
Буковинський державний медичний університет
м. Чернівці, Україна
<https://doi.org/10.5281/zenodo.19556720>

ЕВОЛЮЦІЯ БІОЛОГІЧНОЇ ЗБРОЇ: ВІД КЛАСИЧНОЇ ЗАГРОЗИ *BACILLUS ANTHRACIS* ДО НОВІТНІХ ВІРУСНИХ ВИКЛИКІВ МАЙБУТНЬОГО

Andrushchak Margarita Oleksandrivna,
Ph.D. in Medicine, Associate Professor of the Department of Infectious Diseases and Epidemiology,
Bukovyna State Medical University,
Chernivtsi, Ukraine.
Kolodnitska Nadia Oleksiivna,
Higher Medical Education Student, 5th Year,
Bukovyna State Medical University,
Chernivtsi, Ukraine.

EVOLUTION OF BIOLOGICAL WEAPONS: FROM THE CLASSIC THREAT OF *BACILLUS ANTHRACIS* TO THE MODERN VIRAL CHALLENGES OF THE FUTURE

Анотація:

У статті досліджується еволюція біологічної зброї: від класичних бактеріальних агентів до новітніх вірусних викликів. На прикладі атак у США 2001 року проаналізовано небезпеку сибірки та проблему створення антибіотикорезистентних штамів. У контексті уроків пандемії COVID-19 розглядається сучасна зміна парадигми біозахисту. Особливу увагу приділено вірусу *Nipah* (*Nipah virus*, *NiV*), як загрозі майбутнього («Хвороба X»), що поєднує високу летальність, здатність до масового поширення та відсутність лікування. Підкреслено критичну небезпеку застосування методів синтетичної біології для штучної модифікації патогенів.

Abstract:

This article examines the evolution of biological weapons: from classic bacterial agents to the latest viral threats. Using the 2001 attacks in the United States as an example, it analyzes the danger posed by anthrax and the problem of the emergence of antibiotic-resistant strains. In the context of the lessons learned from the COVID-19 pandemic, the article examines the current paradigm shift in biosecurity. Particular attention is paid to the *Nipah virus* as a future threat (“Disease X”), which combines high lethality, the potential for widespread transmission, and the lack of a cure. The critical danger of using synthetic biology methods for the artificial modification of pathogens is emphasized.

Ключові слова: біологічна зброя; сибірка; *Bacillus anthracis*; аерозольне зараження; військова епідеміологія; антибіотикорезистентність; біозахист; вірус *Nipah*; Хвороба X; агротероризм.

Key words: biological weapons; anthrax; *Bacillus anthracis*; aerosol contamination; military epidemiology; antibiotic resistance; biosecurity; *Nipah virus*; Disease X; agroterrorism.

Мета дослідження: Проаналізувати епідеміологічні та біотехнологічні особливості класичної біологічної зброї на прикладі *Bacillus anthracis* та оцінити сучасні тенденції медичного захисту від антибіотикорезистентних штамів. Водночас дослідити зміну парадигми глобального біозахисту й обґрунтувати новітні загрози майбутнього, пов'язані з потенціалом вірусу *NiV* та ризиками використання методів синтетичної біології.

Матеріали та методи: Для пошуку даних використовувалися джерела з (PubMed, Web of Science, Elsevier та Google Scholar). Був застосований бібліосемантичний та концептуальний методи.

Вступ: У природі легенева сибірка зустрічається вкрай рідко, зазвичай люди хворіють на шкірну форму після контакту з хворими тваринами. Поява навіть одного випадку легеневої форми серед людей, не пов'язаних із сільським господарством, для епідеміологів є першим сигналом про застосування біологічної зброї [1].

Випадок із зараженням сибіркою стався у США в 2001 році після теракту 11 вересня. Перша порція листів зі спорами сибірської виразки була розіслана за тиждень часу. Десятки листів надійшли в кілька офісів ЗМІ й двом сенаторам. Сибірською виразкою тоді заразилися кілька працівників пошти, що сортували конверти, і офісні службовці, які розбирали кореспонденцію. За два

тижні помер у лікарні журналіст Роберт Стівенс, який розпечатав конверт. 22 людини заразилися сибірською виразкою [2].

Генетичний аналіз показав, що в листах використовувався так званий штам Ames, який не є "диким" штамом, він був еталонним і зберігався в лабораторіях, зокрема в Інституті медичних досліджень інфекційних хвороб армії США [3].

Клінічна картина була більш різноманітною через специфіку контакту зі спорами. З двадцяти двох підтверджених випадків рівно половина припала на легенеvu форму, а інша половина на шкірну. У пацієнтів з інгаляційним зараженням спостерігалися лихоманка, озноб та сильна втома. Проте головною діагностичною ознакою, що дозволила американським лікарям швидко встановити правильний діагноз, стало розширення середостіння та накопичення рідини в плевральній порожнині, які було чітко видно на рентгенівських знімках. Завдяки вчасному застосуванню сучасної інтенсивної терапії летальність при легенеvій формі вдалося знизити до 45%. Шкірна форма, яка виникала у людей, що безпосередньо торкалися заражених конвертів, проявлялася локально. Спочатку на відкритих ділянках тіла з'являлася невелика свербляча пляма, яка за кілька днів перетворювалася на пухирець. Згодом він лопався, утворюючи характерну безболісну виразку з чорним некротичним струпом у центрі та сильним набряком навколо. Усі пацієнти зі шкірною формою успішно одужали завдяки антибіотикотерапії [4].

У природних умовах спори сибірки здатні злипатися одна з одною через статичну електрику і швидко осідати на землю. Щоб вони тривалий час висіли в повітрі у вигляді невидимої хмари і проникли глибоко в альвеоли легень необхідна складна технологічна обробка. У США, за даними слідства, застосовувалися спеціальні методи очищення, щоб порошок був максимально сипучим і легко розлітався [5].

Атаки 2001 року у США змусили уряди розробити сучасні алгоритми масової постконтактної профілактики, ініціювати мільярди у датчики виявлення біологічних загроз у повітрі та посилити контроль над патогенами подвійного призначення.

Результати дослідження та їх обговорення: Сучасний етап розвитку біологічної зброї передбачає не стільки пошук нових збудників, скільки вдосконалення вже відомих. Хоча *Bacillus anthracis* є класичним агентом, її найвища сучасна небезпека полягає у цілеспрямованій селекції або генетичній модифікації для створення мультирезистентних штамів. Стандартні військові та цивільні протоколи масової постконтактної профілактики у разі аерозольної атаки базуються на негайному застосуванні антибіотиків першої лінії, зокрема фторхінолонів (ципрофлоксацину) та тетрациклінів (доксцикліну). Проте лабораторні дослідження доводять, що збудник сибірки може відносно легко набувати стійкості до цих препаратів *in vitro*. Застосування такого модифікованого штаму здатне нівелювати ефективність стандартної військової аптечки, що в

умовах бойових дій призведе до неконтрольованого зростання летальності [6].

У відповідь на загрозу застосування антибіотикорезистентних штамів, сучасна військова медицина та епідеміологія змістили фокус на альтернативні методи лікування, які не залежать від чутливості бактерії до антибіотиків. Провідним напрямком стало використання антитоксинів - рекомбінантних моноклональних антитіл, таких як раксібакумаб, які безпосередньо блокують дію летального токсину сибірки в організмі [7].

Якщо історичні програми з розробки біологічної зброї фокусувалися на високолетальних бактеріях (сибірка, чума), то сучасні епідеміологічні прогнози вказують на зміну парадигми. Глобальна пандемія COVID-19, хоча і не є наслідком застосування біологічної зброї за консенсусом світової наукової спільноти, стала безпрецедентним "стрес-тестом" для систем біозахисту. Вона довела, що ідеальному біоагенту сучасності не обов'язково мати 100% летальність. Висока контагіозність, наявність безсимптомних носіїв та тривалий інкубаційний період здатні переважити медичну систему, викликати паніку та завдати катастрофічних економічних збитків цілим державам [8].

Ця зміна парадигми офіційно визнана на рівні Всесвітньої організації охорони здоров'я (ВООЗ), яка ввела концепцію «Хвороби X». Цей термін позначає гіпотетичну патогенну загрозу, що здатна викликати серйозну міжнародну епідемію. З огляду на ці фактори, однією з найбільших загроз майбутнього, яку ніколи раніше не використовували як зброю, експерти вважають вірус NiV. Цей зоонозний вірус стабільно входить до пріоритетного списку ВООЗ щодо розробки екстрених заходів реагування [9].

Вірус Ніпах викликає особливе занепокоєння військових епідеміологів з декількох причин. По-перше, висока летальність при інфікуванні становить від 40% до 75% , розвивається гострий респіраторний синдром та важкий енцефаліт, що наближає його до вірусу Ебола. По-друге, спалахи в Індії та Бангладеш підтвердили здатність вірусу передаватися від людини до людини повітряно-краплинним шляхом.

Історично перший масштабний спалах інфекції у Малайзії продемонстрував здатність вірусу інфікувати сільськогосподарських тварин. Це призвело не лише до людських жертв, але й змусило уряд знищити понад мільйон голів свиней. В умовах гіпотетичної біологічної війни цілеспрямоване зараження тваринницьких комплексів подібним збудником здатне паралізувати продовольчу безпеку цілої країни [10].

Сценарій, якого найбільше побоюються експерти з біотероризму є застосування методів синтетичної біології для модифікації подібних вірусів. Цей напрямок науки відомий як "дослідження подвійного призначення". Здешевлення та доступність сучасних технологій редагування створюють безпрецедентний ризик того, що недержавні актори або терористичні групи зможуть втручатися у генетичний код патогенів. Якщо штучно

поєднати природну летальність вірусу Ніпах із підвищеним рівнем контагіозності респіраторних вірусів (таких як SARS-CoV-2), це створить збудник з апокаліптичним потенціалом, проти якого сучасні протоколи епідеміологічного стримування будуть абсолютно безсилими [11].

Висновок: Історичний досвід чітко показує, що сибірка залишається надзвичайно небезпечною біологічною зброєю. Якщо спеціально підготовлені спори розпорошити в повітрі, вони викликають легеневу форму хвороби, яка без негайного лікування має надвисоку летальність. Сьогодні головна небезпека класичних бактеріальних агентів полягає у їхній можливій лабораторній модифікації. Створення антибіотикорезистентних штамів здатне нівелювати дію стандартних препаратів, що змушує сучасну медицину шукати альтернативні ліки, зокрема антитоксини.

Водночас глобальна парадигма біозахисту кардинально змінюється. Сучасні епідеміологічні прогнози доводять, що гіпотетичною зброєю майбутнього можуть стати новітні зоонозні віруси, такі як вірус Ніпах. Розвиток синтетичної біології та технологій подвійного призначення створює можливість штучно поєднати високу летальність таких вірусів із їхньою здатністю масово поширюватися повітряно-краплинним шляхом. Це вимагає від міжнародної спільноти докорінного перегляду алгоритмів епідеміологічного стримування та готовності до принципово нових біологічних загроз.

Список використаних джерел:

1. Chambers J. Anthrax Infection / J. Chambers, S. N. S. Yarrarapu, M. Afzal, J. K. Mathai // StatPearls [Internet]. – Treasure Island (FL) : StatPearls Publishing, 2024.
2. Jernigan D. B. Investigation of bioterrorism-related anthrax, United States, 2001: epidemiologic findings / D. B. Jernigan, P. L. Raghunathan, B. P. Bell

[et al.] // Emerging Infectious Diseases. – 2002. – Vol. 8, № 10. – P. 1019–1028.

3. Review of the Scientific Approaches Used During the FBI's Investigation of the 2001 Anthrax Letters / National Research Council. – Washington, DC : The National Academies Press, 2011. – 332 p.

4. Bioterrorism-related inhalational anthrax: the first 10 cases reported in the United States. J A Jernigan¹, D S Stephens¹, D A Ashford. PMID: PMC2631903 PMID: 11747719.

5. Molecular Subtyping of Bacillus anthracis and the 2001 Bioterrorism-Associated Anthrax Outbreak, United States (Hoffmaster et al., 2002).

6. Effect of substrate exposure and other growth condition manipulations on norA expression. Glenn W Kaatz, Susan M Seo. PMID: 15231765. DOI: 10.1093/jac/dkh341.

7. Kummerfeldt C. E. Raxibacumab: potential role in the treatment of inhalational anthrax / C. E. Kummerfeldt // Infection and Drug Resistance. – 2014. – Vol. 7. – P. 101–109.

8. The COVID-19 Response Has Uncovered and Increased Our Vulnerability to Biological Warfare Regan F Lyon. Affiliations Expand. PMID: 33585895. PMID: PMC7928741. DOI: 10.1093/milmed/usab061.

9. Mehand M. S. The WHO R&D Blueprint: 2018 review of emerging infectious diseases requiring urgent research and development efforts / M. S. Mehand, F. Al-Shorbaji, P. Millett, B. Murgue // Antiviral Research. – 2018. – Vol. 159. – P. 63–67.

10. Epstein J. H. Nipah virus: impact, origins, and causes of emergence / J. H. Epstein, H. E. Field, S. Luby [et al.] // Current Infectious Disease Reports. – 2006. – Vol. 8, № 1. – P. 59–65.

11. MacIntyre C. R. Biopreparedness in the age of genetically engineered pathogens and open access science: an urgent need for a paradigm shift / C. R. MacIntyre // Military Medicine. – 2015. – Vol. 180, № 9. – P. 943–949.

Нурмаматова К. Ч.,
Ташкентский государственный медицинский университет
Шавкиев Д. П., Тангиров А. Л., Хайдаров С. Н.
Военно-медицинский институт

УРОВЕНЬ ИНФОРМИРОВАННОСТИ СЕМЕЙНЫХ ВРАЧЕЙ ПО ВОПРОСАМ АЛЛЕРГОПАТОЛОГИИ У ДЕТЕЙ

Nurmatova K. Ch.,
Tashkent State Medical University.
Shavkiev D. P., Tangirov A. L., Khaidarov S. N.,
Military Medical Institute.

LEVEL OF AWARENESS AMONG FAMILY DOCTORS REGARDING PEDIATRIC ALLERGOPATHOLOGY

Аннотация:

В статье представлены данные анализа основных факторов, оказывающих влияние на качество оказания медицинской помощи детям, страдающими аллергическими заболеваниями. Проведенный опрос семейных врачей поликлиник позволил прийти к заключению, что еще имеются ряд недостатков в организационных вопросах выявления, взятия на учет, лечения детей с аллергическими заболеваниями, решение которых позволит повысить качество аллергологической помощи на уровне первичного звена здравоохранения.

Abstract:

This article presents an analysis of the main factors influencing the quality of medical care for children with allergic diseases. A survey of family physicians at outpatient clinics revealed a number of organizational gaps in the identification, registration, and treatment of children with allergic diseases. Addressing these gaps will improve the quality of allergy care at the primary healthcare level.

Ключевые слова: аллергические заболевания, дети, семейные поликлиники, семейные врачи, качество медицинской помощи.

Keywords: allergic diseases, children, family clinics, family physicians, quality of medical care.

Введение. Одним из актуальных вопросов здравоохранения является повышение качества медицинской помощи, в том числе и в учреждениях первичного – амбулаторно-поликлинического звена [6,7,10]. В настоящее время большое внимание в Узбекистане уделяется повышению качества оказываемых медицинских услуг. Особенно актуальным этот вопрос является для деятельности учреждений ПМСП. На данном этапе нами были выявлены некоторые проблемы в СП столицы Узбекистана по организации профилактических осмотров детей с целью выявления АЗ. Правильная организация работы семейных поликлиник в значительной степени способна сократить затраты на дальнейшие лечебные и реабилитационные мероприятия при аллергических заболеваниях (АЗ) [1,2,4].

Цель исследования: выявление организационных проблем, с которыми сталкиваются врачи амбулаторно-поликлинических учреждений зоны ПМСП при проведении скрининга и диспансеризации детей с аллергиями.

Материал и методы исследования: для анализа организационных проблем в семейных поликлиниках было проведено анонимное анкетирование 60 семейных врачей семейных поликлиник г. Ташкента. Анкетирование проводилось по специально разработанной анкете. Анкета включала в себя 3 блока вопросов – демографические данные,

сведения об организации приема пациентов и диспансеризации больных с АЗ и группы риска.

Все опрошенные нами врачи семейных были женщины средний возраст которых соответствовал $42,4 \pm 1,7$ лет. Из общего числа опрошенных только 13,3% имели стаж работы менее 10 лет, у остальных стаж был 10 и более лет, среди которых у 21,7% стаж был более 30 лет.

Результаты исследования: Одной из обязательных составляющих качества медицинской помощи в лечебно-поликлинических учреждениях является ее ресурсное обеспечение, которое включает обеспеченность качественными кадрами, современную материально-техническую базу, условия работы врачей их психологический статус.

Одним из важнейших факторов, влияющих на качество работы специалистов является комфортный психологический микроклимат, однако только 41,7% респондентов оценили его как благоприятный. На отсутствие взаимопонимания с коллегами обратили внимание 25,0% респондентов. Более трети респондентов 35,0% не находят общего языка и поддержки у руководства поликлиники. Снижает мотивацию к полноценному труду и низкая заработная плата, особенно при повышенной физической и психологической нагрузке. Подавляющее большинство респондентов 90,0% были недовольны своей заработной платой. Три четверти семейных врачей (75,0%) отметили недостаток вре-

мени для общения с больным ребенком и его родителями. Практически все врачи связали это с чрезмерным количеством заполняемой медицинской документации (95,0%). Необходимо отметить, что и в настоящее время не у всех врачей имеются компьютеры на рабочих мест, которые, по мнению врачей, могли бы уменьшить работу с документами. Почти половина врачей (46,7%) в виду их загруженности на работе не могут уделить времени на самоподготовку, а более треть из них 36,7% пожалова-

лись на недостаточное количество образовательных программ, в том числе по аллергологии.

Рассматривая вопросы непосредственно влияющие на качество диспансеризации детей с аллергопатологией (табл.1), необходимо отметить, что 60 респондентов дали в общей сложности 254 ответа, то есть каждый семейный врач (СВ) назвал более 4 факторов, негативно влияющих на качество оказания лечебно профилактической помощи детям с АЗ.

Таблица 1.

Факторы, влияющие на качество диспансеризации детей с аллергическими заболеваниями по мнению семейных врачей поликлиник г. Ташкента.

| Фактор | Число ответов | Частота на 100 респондентов (n = 60) (P<0,05) |
|--|---------------|---|
| Позднее обращение родителей с детьми за медицинской помощью | 22 | 36,7±6,2 |
| Низкий объем диагностических исследований в поликлинике | 41 | 68,3±6,0 |
| Трудности в оформлении направления пациента с АЗ на консультацию в РНПЦАЗ | 16 | 26,7±5,7 |
| Трудности в оформлении ордера на госпитализацию | 16 | 26,7±5,7 |
| Отсутствие аллерголога в поликлинике | 54 | 90,0±3,9 |
| Не качественное лабораторное обслуживание | 17 | 28,3±5,8 |
| Недостаток информации по аллергологии | 22 | 36,7±6,2 |
| Отсутствие взаимосвязи между учреждениями, отвечающими за диспансеризацию больных с АЗ | 12 | 20,0±5,2 |
| Недостаточная ответственность родителей в осуществлении мероприятий по профилактике и лечению ребенка | 37 | 61,7±6,3 |
| Недостаточная ответственность врачей в осуществлении мероприятий диспансеризации ребенка с аллергопатологией | 17 | 28,3±5,8 |
| Всего ответов | 254 | 4,2:1 |

На первое место по значимости выявления и качественной диспансеризации детей с АЗ врачи поликлиники поставили наличие районного аллерголога. По мнению 90,0% опрошенных отсутствие аллерголога в центральной поликлинике отрицательно влияет на выявляемость и дальнейшее лечение больных с АЗ. Недостаточная техническая и диагностическая база поликлиники в 68,3% приводит к гипер- или гиподиагностике АЗ и вынуждает пациентов обращаться в частные учреждения, РНСАЦ и другие учреждения республиканского масштаба, где эта диагностика осуществляется на платной основе, что в свою очередь уменьшает уровень обращаемости пациентов с начальными или легкими формами АЗ.

К снижению уровня обращаемости в специализированные учреждения в 26,7% случаев способствует трудность (обилие документов, резолюций и затрат времени пациента) при оформлении направлений на консультацию или ордеров на госпитализацию в государственные структуры. Это приводит к тому, что больные напрямую обращаются в частные или республиканские учреждения с последующим лечением и наблюдением у них, что зачастую приводит к выпадению данных пациентов из поля зрения поликлиник и в конечном итоге скрывает истинный размер проблемы распространенности

АЗ среди детей в масштабах данного района и влияет на планирование профилактических мероприятий. Этому же по мнению каждого пятого врача (20,0%) способствует низкий уровень взаимосвязи между учреждениями, отвечающими за диспансеризацию больных с АЗ.

Важным элементом диспансеризации при любом заболевании является личная ответственность врачей в осуществлении мероприятий по профилактике, выявлению, лечению и дальнейшему наблюдению пациента, однако 28,3% врачей признают, что в настоящее время эта ответственность находится на достаточно низком уровне. Однако, большинство врачей 61,7% считают, что к низким показателям качества диспансеризации и ухудшению состояния пациента, приводит недостаточная ответственность и родителей детей больных АЗ и самих детей. Это проявляется в небрежном отношении к выполнению предписаний врача (не регулярность посещения врача, элементы самолечения, нарушение диеты и пр.). Очень часто заболевание у ребенка диагностируется в поздних стадиях именно потому, что 36,7% больных обращаются за помощью к врачу поздно.

Для определения уровня информированности врачей в вопросах профилактики, диагностики и лечения пациентов с АЗ нами были заданы нашим респондентам соответствующие вопросы (табл. 2).

Уровень информированности СВ семейных поликлиник г. Ташкента о аллергических заболеваниях у детей

| Ответы | Число правильных ответов | Частота правильных ответов на 100 респондентов (n = 60) (P<0,05) |
|---|--------------------------|--|
| Что такое ISAAC | 35 | 58,3±6,4 |
| Что такое атопический марш | 43 | 71,7±5,8 |
| Что такое перекрестная аллергия | 28 | 46,7±6,4 |
| Как проводятся кожные пробы | 56 | 93,3±3,2 |
| Где проводятся провокационные пробы | 31 | 51,7±6,3 |
| Что такое элиминационный тест | 35 | 58,3±6,3 |
| Какие продукты наиболее часто вызывают пищевую аллергию у детей | 35 | 58,3±6,3 |
| Какие учреждения в городе осуществляют диагностику и лечение больных с АЗ | 43 | 71,7±5,8 |
| Средний уровень правильных ответов | | 63,8±1,8 |

Опрос СВ (семейный врач) показал среднюю информированность врачей в вопросах аллергопатологии. Только на вопрос «Как проводятся кожные пробы» было получено 93,3% правильных ответов. Что такое атопический марш знали 71,7% врачей. С понятием перекрестной аллергии знакомы только 46,7% респондентов. С международной программой выявления АР и БА ISAAC, понятием элиминационного теста и тем какие продукты наиболее часто провоцируют пищевую аллергию правильно ответили 58,3% респондентов. Средний уровень информированности семейных врачей по всем вопросам об аллергопатологии составил 63,8. Недостаточная информированность практических врачей семейных поликлиник в проблематике АЗ, по мнению 36,7% самих специалистов, связана с недостаточным количеством обучающих программ и информации по аллергиям у детей, имеющихся в их распоряжении.

Отсутствие аллергологов-иммунологов в многопрофильных семейных поликлиниках, вынуждает семейных врачей направлять детей с подозрением на аллергии для специфической диагностики и лечения в другие учреждения. Из общего числа больных, обратившихся в территориальные поликлиники по поводу АЗ, 61,7% были направлены в РНСАЦ; 20,0% в частные диагностические центры; в стационары 13,3% и в другие научно-практические центры и клиники Вузов 5,0%.

Важную роль в профилактике и раннем выявлении АЗ играет просветительская работа среди населения. ФЗОЖ является обязательной функцией врачей в первичном звене здравоохранения. Все опрошенные были согласны с тем, что проведение массовых мероприятий по пропаганде знаний среди населения по вопросам АЗ являются одной из наиболее действенных мер по профилактике данной патологии детского возраста. К сожалению, только 68,3% врачей проводили массовые мероприятия (беседы и лекции) по данной тематике среди жителей махалли. В организации правильного ухода и питания детей из группы риска развития АЗ или аллергиков большую роль играет правильная

подготовка членов семьи пациента в данном вопросе. Максимально приемлемой формой такой работы является курсовое обучение в «Школе аллергии», однако такая форма работы существует только в РНСАЦ и только 38,3% из опрошенных врачей направляли туда детей из группы риска или больных с аллергиями.

Выводы: таким образом, на качество организации профилактики, диагностики и дальнейшего лечения, и наблюдения за детьми с АЗ в поликлиниках наибольшее влияние оказывают:

- отсутствие детских аллергологов на уровне районного медицинского объединения;
- низкая заинтересованность и информированность врачей в вопросах раннего выявления и диспансеризации детей с данной патологией;
- недостатки в обследовании пациентов на уровне первичного звена в результате низкой технической оснащённости;
- отсутствие соответствующих программ по выявлению факторов риска среди беременных и родителей с детьми младенческого возраста.
- недооценка родителями основных факторов риска данной патологии, начальных проявлений болезни, нарушения предписанного режима лечения и воспитания ребенка с АЗ;
- низкая медицинская активность и информированность родителей.

Список литературы:

1. Булешов М. А. Оценка влияния комплекса социально-гигиенических факторов риска на состояние здоровья детей / М. А. Булешов, С. А. Туктибаева // Вестник Каз НМУ. – Казань, 2020. - №4. - С. 557-563.
2. Квалификационная характеристика на врачебную специальность –аллергология и иммунология// Министерство здравоохранения Узбекистана <https://www.minzdrav.uz/documentation>
3. Мухаммадова Х.Х. Умурова Н. А., Хамдамов И. И. Особенности острых аллергических состояний у детей, проектирующих в экологическом неблагоприятном регионе // Актуальные проблемы гуманитарных и естественных наук. – 2017. – №11-2. – С. 82-85.

4. Ризаев Ж.А., Нурмаганова К.Ч., Рустамова Х.Е. Медико-организационные аспекты профилактики аллергических заболеваний среди детского населения. / [Монография]. — Ташкент.: “GRAND KONDOR PRINT”, 2025 г., 124 с.
5. Овсянников Д.Ю. Основы клинической иммунологии и аллергологии детского возраста: - Учебное пособие.-М.: ИПК РУДН, 2022. – 134 с. - 75 с
6. Орел В.И., Ким А.В. Организация работы отделения (кабинета) медико-социальной помощи в детской поликлинике. Метод. пособие. ГБОУ ВПО СПбГПМУ Минздрава России. 2016.
7. Постановление Президента Республики Узбекистан № ПП - 2857 от 29. 03. 2017 г. О мерах по совершенствованию организации деятельности учреждений первичной медико-санитарной помощи Республики Узбекистан// Национальная база данных законодательства. – 29.06.2020 г., № 06/20/5370/0975
8. Постановление Президента Республики Узбекистан № ПП 3715 от 11.05.2018 О мерах по коренному совершенствованию профилактики диагностики и лечения аллергических заболеваний//Национальная база данных законодательства, 14.05.2018 г., № 07/18/3715/1200
9. Рустамова Х.Е. Стожарова Н.К. Вопросы реформирования системы здравоохранения Республики Узбекистан (часть 2)// Организация и управление здравоохранением № 6 (72), 2016 С. 46-54.
10. Руселевич М.В. Медико-социальная проблема респираторных аллергозов в крупном городе// Электронный научный журнал «Социальные аспекты здоровья населения». - 2018. – 8 с. DOI: 10.21045/2071-5021-2018-60-2-5
11. Указ Президента Республики Узбекистан «О мерах по внедрению принципиально новых механизмов в деятельность учреждений первичной медико-санитарной помощи и дальнейшему повышению эффективности проводимых в системе здравоохранения реформ» №УП-5590 от 12.11. 2020//
12. Тураева Д.М., Халматова Б.Т. Распространенность аллергических заболеваний у детей, проживающих в промышленных городах (по данным анкетирования)// Научно-исследовательские публикации. - 2015. - №11 (31). - С 51 -54.

Опасць Мар'яна Федорівна
студентка 5 курсу, спеціальність 222 "Медицина"
Давиденко Оксана Миколаївна
доцент, кандидат медичних наук,
доцент закладу вищої освіти кафедри інфекційних хвороб та епідеміології
Буковинський державний медичний університет
м. Чернівці, Україна
<https://doi.org/10.5281/zenodo.19556764>

ОСОБЛИВОСТІ КЛІТИННОГО ІМУНІТЕТУ ПРИ ХРОНІЧНИХ ВІРУСНИХ ІНФЕКЦІЯХ (ВІЛ, HBV, HCV)

Opacts Mariana Fedorivna
5th year student, specialty 222 "Medicine"
Davydenko Oksana Mykolaivna
PhD MD, Associate Professor of the Department of Infectious Diseases and Epidemiology
Bukovinian State Medical University
Chernivtsi, Ukraine

FEATURES OF CELLULAR IMMUNITY IN CHRONIC VIRAL INFECTIONS (HIV, HBV, HCV)

Анотація.

Хронічні вірусні інфекції, зокрема ВІЛ, вірус гепатиту В (HBV) та вірус гепатиту С (HCV), залишаються однією з провідних медико-соціальних проблем сучасності. Вони характеризуються тривалим персистуванням вірусу в організмі та формуванням складних механізмів імунної дисрегуляції. Центральну роль у контролі вірусної інфекції відіграє клітинний імунітет, зокрема CD4+ та CD8+ Т-лімфоцити, NK-клітини та антигенпрезентуючі клітини. При хронізації інфекції відбувається виснаження Т-клітин, зниження їх функціональної активності та розвиток імунної толерантності. Особливе значення мають процеси експресії інгібіторних рецепторів, таких як PD-1, CTLA-4, що пригнічують протівірусну відповідь. Також важливими є зміни цитокінового профілю, зсув у бік імуносупресивних реакцій та порушення кооперації між клітинними ланками імунітету. Розуміння цих механізмів є ключовим для розробки нових терапевтичних стратегій, включаючи імунотерапію.

Abstract.

Chronic viral infections such as HIV, hepatitis B virus (HBV), and hepatitis C virus (HCV) remain a major global health concern. These infections are characterized by persistent viral replication and complex immune dysregulation mechanisms. Cellular immunity plays a central role in viral control, particularly involving CD4+ and CD8+ T lymphocytes, natural killer cells, and antigen-presenting cells. Chronic infection leads to T-cell exhaustion, reduced functional activity, and the development of immune tolerance. The expression of inhibitory receptors such as PD-1 and CTLA-4 is crucial in suppressing antiviral responses. Additionally, alterations in cytokine profiles and impaired cellular interactions contribute to disease progression. Understanding these mechanisms is essential for the development of novel therapeutic strategies, including immunotherapy.

Ключові слова: клітинний імунітет, ВІЛ, HBV, HCV, Т-лімфоцити, імунна відповідь, імунна толерантність, виснаження Т-клітин, цитокіни.

Key words: cellular immunity, HIV, HBV, HCV, T lymphocytes, immune response, immune tolerance, T-cell exhaustion, cytokines.

Хронічні вірусні інфекції становлять серйозну проблему сучасної медицини через здатність вірусів уникати імунного контролю та персистувати в організмі протягом тривалого часу. Особливе місце серед них займають ВІЛ, HBV та HCV, які характеризуються складною взаємодією з імунною системою, що призводить до формування імунної дисфункції та прогресування захворювання [1]. Ключову роль у протівірусному захисті відіграє клітинний імунітет, який включає Т-лімфоцити, природні кілерні клітини та антигенпрезентуючі клітини [2].

У гострій фазі вірусної інфекції активується потужна клітинна імунна відповідь, яка спрямована

на елімінацію інфікованих клітин. CD8+ цитотоксичні Т-лімфоцити розпізнають вірусні антигени, представлені молекулами головного комплексу гітосомічності I класу, та індукують апоптоз інфікованих клітин [3]. CD4+ Т-хелпери відіграють допоміжну роль, стимулюючи продукцію цитокінів і підтримуючи функцію CD8+ клітин [4]. Проте при переході інфекції у хронічну форму ефективність цієї відповіді значно знижується.

Однією з ключових особливостей хронічних вірусних інфекцій є феномен виснаження Т-клітин. Він характеризується поступовою втратою проліферативної здатності, зниженням продукції інтерферону- γ , TNF- α та інших цитокінів, а також підвищеною експресією інгібіторних рецепторів, таких

як PD-1, CTLA-4, TIM-3 [5]. Цей процес добре описаний при ВІЛ-інфекції, де спостерігається прогресивне зниження кількості CD4+ Т-лімфоцитів і порушення функції CD8+ клітин [6].

При HBV-інфекції імунна відповідь значною мірою визначає результат захворювання. У разі ефективної відповіді відбувається кліренс вірусу, тоді як при недостатній активації Т-клітин формується хронічна інфекція [7]. У таких пацієнтів спостерігається зниження функціональної активності CD8+ Т-лімфоцитів і зменшення продукції противірусних цитокінів [8]. Подібні механізми характерні і для HCV-інфекції, де вірус здатний уникати імунного контролю шляхом мутацій і пригнічення клітинної відповіді [9].

Важливу роль у розвитку хронічної інфекції відіграє порушення функції антигенпрезентуючих клітин, зокрема дендритних клітин. При ВІЛ та HCV спостерігається зниження їх здатності до презентації антигену та активації Т-лімфоцитів [10]. Це призводить до недостатньої ініціації імунної відповіді та сприяє персистенції вірусу.

NK-клітини також зазнають функціональних змін при хронічних вірусних інфекціях. Вони можуть втрачати цитотоксичну активність або змінювати профіль рецепторів, що впливає на їх здатність розпізнавати інфіковані клітини [11]. При ВІЛ-інфекції описано дисбаланс між активуючими та інгібіторними сигналами, що призводить до зниження ефективності NK-клітин [12].

Цитокіновий профіль при хронічних інфекціях також зазнає суттєвих змін. Відбувається зсув у бік імуносупресивних цитокінів, таких як IL-10 та TGF- β , що пригнічують клітинну імунну відповідь [13]. Одночасно знижується продукція інтерферонів, які є ключовими медіаторами противірусного захисту [14]. Такий дисбаланс сприяє підтриманню хронічного запалення та вірусної персистенції.

Окрему роль у формуванні хронічної вірусної інфекції відіграють метаболічні зміни імунних клітин. У нормі активація Т-лімфоцитів супроводжується переходом до гліколітичного метаболізму, що забезпечує їх швидку проліферацію та ефекторні функції. Проте при тривалій антигенній стимуляції, характерній для хронічних інфекцій, відбувається метаболічне виснаження клітин, зниження мітохондріальної функції та порушення енергетичного балансу. Це додатково обмежує здатність імунної системи ефективно контролювати вірус.

Особливе значення має роль регуляторних Т-клітин (Treg), які пригнічують імунну відповідь і сприяють розвитку імунної толерантності. При HBV та HCV їх кількість і активність зростають, що асоціюється з хронізацією інфекції [15]. Аналогічні зміни спостерігаються і при ВІЛ, де Treg можуть обмежувати ефективність противірусної відповіді [16].

Важливим аспектом імунної дисфункції є також зміни у формуванні імунологічної пам'яті. При хронічних вірусних інфекціях порушується диференціація довгоживучих пам'ятевих Т-клітин, що

знижує здатність організму до швидкої та ефективної відповіді при повторній активації вірусу. Замість цього переважають фенотипи клітин із ознаками виснаження, що обмежує тривалий захисний імунітет навіть за умов часткового контролю вірусної реплікації.

Механізми імунного виснаження активно досліджуються у контексті нових терапевтичних підходів. Одним із перспективних напрямків є блокада інгібіторних рецепторів, зокрема PD-1/PD-L1, що дозволяє відновити функцію Т-клітин [17]. Такі підходи вже використовуються в онкології та поступово вивчаються при хронічних вірусних інфекціях [18].

ВІЛ-інфекція характеризується глибоким ураженням імунної системи, що проявляється прогресуючим зниженням CD4+ Т-лімфоцитів і розвитком імунодефіциту [19]. Антиретровірусна терапія дозволяє частково відновити імунну функцію, однак повного відновлення клітинного імунітету досягти складно [20]. При цьому зберігається стан хронічної імунної активації, що негативно впливає на прогноз [21].

HBV-інфекція характеризується складною взаємодією між вірусом і імунною системою, де імунна відповідь може бути як захисною, так і патогенною, спричиняючи ушкодження печінки [22]. При HCV-інфекції важливу роль відіграє генетична варіабельність вірусу, яка дозволяє йому уникати імунного контролю [23].

Сучасні дослідження також приділяють значну увагу ролі епігенетичних змін у регуляції імунної відповіді при хронічних вірусних інфекціях. Встановлено, що тривала експресія інгібіторних рецепторів і функціональне виснаження Т-клітин супроводжуються стабільними епігенетичними перебудовами, які фіксують цей дисфункціональний стан. Це пояснює, чому навіть після зниження вірусного навантаження імунна система не завжди повністю відновлює свою функціональність.

Таким чином, клітинний імунітет при хронічних вірусних інфекціях зазнає глибоких змін, що включають виснаження Т-клітин, порушення функції антигенпрезентуючих клітин, дисбаланс цитокінів та підвищення активності регуляторних механізмів [24]. Розуміння цих процесів є ключовим для розробки нових методів лікування та покращення прогнозу пацієнтів [25].

Висновок

Хронічні вірусні інфекції супроводжуються глибокими порушеннями клітинного імунітету, що проявляються виснаженням Т-лімфоцитів, змінами цитокінового профілю та розвитком імунної толерантності. Центральну роль у цих процесах відіграє дисбаланс між ефекторними та регуляторними механізмами імунної відповіді. Незважаючи на досягнення сучасної медицини, повне відновлення імунної функції залишається складним завданням. Подальші дослідження у цій сфері відкривають перспективи для впровадження нових імунотерапевтичних підходів, спрямованих на відновлення ефективної противірусної відповіді.

Список використаних джерел

1. McLane L.M., Abdel-Hakeem M.S., Wherry E.J. CD8 T cell exhaustion during chronic viral infection. *Annual Review of Immunology*. 2019;37:457–495.
2. Blank C.U., Haining W.N., Held W., Hogan P.G., Kallies A., Lugli E., et al. Defining 'T cell exhaustion'. *Nature Reviews Immunology*. 2019;19(11):665–674.
3. Wherry E.J., Kurachi M. Molecular and cellular insights into T cell exhaustion. *Nature Reviews Immunology*. 2015;15(8):486–499.
4. Pauken K.E., Wherry E.J. Overcoming T cell exhaustion in infection and cancer. *Nature Reviews Immunology*. 2019;19(7):425–437.
5. McMichael A.J., Picker L.J. Unravelling the immune response to HIV. *Nature Reviews Immunology*. 2017;17(5):321–332.
6. Deeks S.G., Overbaugh J., Phillips A., Buchbinder S. HIV infection. *Nature Reviews Disease Primers*. 2015;1:15035.
7. Deeks S.G., Lewin S.R., Havlir D.V. The end of AIDS: HIV infection as a chronic disease. *Lancet*. 2013. McGary C.S., Deleage C., Harper J., Micci L.,
8. Ribeiro S.P., Paganini S., et al. CTLA-4+PD-1+ memory CD4+ T cells contribute to HIV persistence. *Immunity*. 2017;46(5):776–788.
9. Bertolotti A., Ferrari C. Adaptive immunity in HBV infection. *Nature Reviews Immunology*. 2016;16(6):389–401.
10. Maini M.K., Burton A.R. Restoring immune control in chronic hepatitis B. *Journal of Hepatology*. 2019;70(4):665–674.
11. Rehermann B., Thimme R. Insights from antiviral therapy into immune responses in hepatitis B and C. *Nature Reviews Immunology*. 2019;19(8):485–502.
12. Kennedy P.T.F., Litwin S., Dolman G.E., Bertolotti A., Mason W.S. Immune tolerant chronic hepatitis B. *Journal of Hepatology*. 2017;66(2):346–356.
13. Walker C.M. Adaptive immunity to hepatitis C virus. *Nature Reviews Immunology*. 2018;18(8):505–513.
14. Dustin L.B. et al. Hepatitis C virus immune evasion. *Nature Reviews Immunology*. 2018;18(6):321–334.
15. Neumann-Haefelin C., Thimme R. Adaptive immune responses in hepatitis C virus infection. *Journal of Clinical Investigation*. 2018;128(6):2250–2260.
16. Palucka K., Banchereau J. Dendritic cells in immunity and cancer. *Nature Reviews Immunology*. 2017;17(8):461–472.
17. Wykes M.N., Lewin S.R. Immune checkpoint blockade in infectious diseases. *Nature Reviews Immunology*. 2018;18(2):91–104.
18. Brooks D.G., Trifilo M.J., Edelmann K.H., et al. IL-10 in chronic viral infection. *Nature Medicine*. 2016;22(10):1091–1100.
19. Ivashkiv L.B., Donlin L.T. Regulation of type I interferon responses. *Nature Reviews Immunology*. 2017;17(12):704–716.
20. Alter G., Altfeld M. NK cells in HIV-1 infection. *Journal of Immunology*. 2017;198(5):1781–1787.
21. Vivier E., Artis D., Colonna M., et al. Innate lymphoid cells: 10 years on. *Nature Immunology*. 2018;19(7):656–663.
22. Schurich A., Pallett L.J., Lubowiecki M., Singh H.D., Gill U.S., Kennedy P.T.F., et al. The third signal cytokine IL-12 rescues the antiviral function of exhausted CD8 T cells. *Journal of Hepatology*. 2016;65(3):499–509.
23. Schietinger A., Greenberg P.D. Tolerance and exhaustion: defining mechanisms of T cell dysfunction. *Nature Reviews Immunology*. 2016;16(12):733–745.
24. Virgin H.W., Wherry E.J., Ahmed R. Redefining chronic viral infection. *Cell*. 2019
25. Utzschneider D.T., Alfei F., Roelli P., et al. High antigen levels induce exhausted T cell differentiation. *Immunity*. 2016;45(2):358–373.

Чоповці Іван Іванович

Студент 5 курсу

Буковинський державний медичний університет

м. Чернівці, Україна

Мироник Олена Володимирівна

доцент кафедри інфекційних хвороб та епідеміології

Буковинський державний медичний університет

м. Чернівці, Україна

<https://doi.org/10.5281/zenodo.19556783>**ПАТОГЕНЕТИЧНІ АСПЕКТИ ДИФТЕРІЙНОГО МІОКАРДИТУ
(ОГЛЯД ЛІТЕРАТУРИ)****Chopovtsi Ivan Ivanovych,**

5th-year student.

Bukovyna State Medical University,

Chernivtsi, Ukraine.

Myronyk Olena Volodymyrivna,

Associate Professor of the Department of Infectious Diseases and Epidemiology.

Bukovyna State Medical University,

Chernivtsi, Ukraine.

**PATHOGENETIC ASPECTS OF DIPHTHERIA MYOCARDITIS
(LITERATURE REVIEW)****Анотація:**

Дифтерійний міокардит є одним із найтяжчих та потенційно летальних ускладнень дифтерії, що призводить до високого рівня смертності навіть за умови своєчасної діагностики та початку лікування захворювання. Клінічні прояви дифтерійного міокардиту варіюють від субклінічних змін на електрокардіограмі до тяжкої серцевої недостатності, важких аритмій та повної синоатріальної блокади. Дифтерійний міокардит зазвичай через 1-2 тижні після початку симптомів дифтерії ротоглотки. Ураження міокарда розвивається внаслідок токсичної дії дифтерійного екзотоксину, який інгібує синтез білка в кардіоміоцитах, спричиняючи їх некроз, порушення провідності та скоротливої функції серця. Дифтерійний екзотоксин вражає мітохондрії кардіоміоцитів, призводячи до їх набряку з втратою матриксу та виснаження глікогену з накопиченням ліпідних крапель всередині.

Abstract:

Diphtheria myocarditis is one of the most severe and potentially fatal complications of diphtheria, leading to a high mortality rate even with timely diagnosis and initiation of treatment. Clinical manifestations of diphtheria myocarditis range from subclinical changes on the electrocardiogram to severe heart failure, life-threatening arrhythmias, and complete sinoatrial block. Diphtheria myocarditis usually occurs 1-2 weeks after the onset of symptoms of oropharyngeal diphtheria. Myocardial damage develops due to the toxic action of diphtheria exotoxin, which inhibits protein synthesis in cardiomyocytes, causing their necrosis, impaired conduction and contractile function of the heart. Diphtheria exotoxin affects the mitochondria of cardiomyocytes, leading to their edema with loss of matrix and depletion of glycogen with the accumulation of lipid droplets inside.

Ключові слова: дифтерія, міокардит, екзотоксин, аритмії, синоатріальна блокада, патогенез**Keywords:** diphtheria, myocarditis, exotoxin, arrhythmias, sinoatrial block, pathogenesis

Матеріали та методи: нами проведений огляд літератури на основі іноземних статей, опублікованих у наукометричних базах даних за останні 10 років. Аналізувалась актуальна інформація щодо патогенетичних аспектів дифтерійного міокардиту.

Мета - було проаналізувати наукові роботи, літературні джерела та визначено патогенетичні аспекти дифтерійного міокардиту.

Актуальність: Дифтерія – це небезпечне для життя захворювання, що спричинене токсигенною *C. diphtheriae* [1]. *Corynebacterium* spp. – це грампозитивні, нерухомі палички з булавоподібною формою, аеробні або факультативно анаеробні. Інфекційними агентами, що викликають дифтерію, є

токсигенні штами *C. diphtheriae* та, рідше, близькоспоріднені *C. ulcerans* та *C. pseudotuberculosis* [2]. Токсигенність залежить від успішної бактеріальної експресії дифтерійного токсину, кодованого геном токсину (*tox*) [3]. Інфікування токсигенними штамми *Corynebacterium diphtheriae* відбувається шляхом вдихання або прямого контакту, з подальшим виникненням респіраторних симптомів після інкубаційного періоду від двох до п'яти днів. Дифтерію можуть передавати як симптоматичні, так і безсимптомні особи [4,5]. Найпоширенішим проявом є захворювання дифтерія ротоглотки, що проявляється набряком мигдаликів та шийним лімфаденітом. Характерною є утворення некротичної

псевдомембрани на мигдаликах, глотці та гортані, що при спробі зняття кровоточить [5]. Також спочатку симптоматика може включати біль у горлі, нездужання, кашель, хрипкий голос, болісне ковтання, кров'янисті виділення з носа та слинотечу [2]. Візуалізація псевдомембрани в ротоглотці підсилює клінічну підозру. Виявлення *S. diphtheriae* за допомогою посіву мазка з горла, або виявлення дифтерійного токсину допомагає підтвердити діагноз. Хоча глобальна захворюваність на дифтерію значно знизилася, завдяки ефективним програмам вакцинації, вона залишається ендемічною в кількох регіонах, де програми вакцинації не підтримуються, та де уражається все більша частка дорослого населення [1].

Результати та їх обговорення: Системне захворювання виникає, коли дифтерійний токсин поширюється в кровотоці, що призводить до токсинопосередкованого пошкодження серця, нирок та периферичних нервів [2]. Ураження серця є основною причиною смертності у цих пацієнтів, що спостерігається у 10–20% пацієнтів з дифтерією ротоглотки [1].

Дифтерійний міокардит ускладнює від 10 до 25% випадків дифтерії ротоглотки [2,5]. Міокардит зазвичай проявляється наприкінці другого тижня інфекції, але при тяжких інфекціях може проявитися раніше. Дифтерійний міокардит колись мав рівень летальності 60%–70%, але в останніх статтях повідомлялося про рівень смертності від 0% до 80% [5,7]. Хоча кардіотоксичність зазвичай розвивається на другому тижні хвороби, важкі випадки можуть проявлятися ураженням серця вже при першому зверненні. Токсин вражає міокард і викликає запалення та порушення роботи вузлової та спеціалізованої провідної тканини, тим самим спричиняючи дилатаційну кардіоміопатію зі зниженою фракцією викиду, кардіогенний шок та низку порушень провідності [5]. Запідозрити дифтерійний міокардит, слід у пацієнтів з гострою серцевою недостатністю, болем у горлі в анамнезі, супутніми неврологічними проявами та ураженням черепних нервів, особливо у невакцинованих від дифтерії осіб [1]. Серцеві прояви дифтерійного міокардиту можуть бути різноманітними та включати дисфункцію міокарда, порушення ритму (брадіаритмії або тахіаритмії) та блокади серця, що потребують кардіостимуляції. Підвищений рівень серцевих ферментів та порушення на електрокардіограмі (ЕКГ) можуть свідчити про безсимптомне ураження міокарда [7-9].

Дифтерійний токсин має гальмівний вплив на активність фактора елонгації 2, що є критичним етапом у синтезі білка. Крім того, він викликає фрагментацію ДНК та цитоліз [10]. Примітно, що гепарин-зв'язуючий епідермальний фактор росту, подібний до фактора росту, який є місцем зв'язування дифтерійного токсину, інтенсивно експресується на клітинних мембранах кардіоміоцитів та нейронів, що сприяє токсичній дії дифтерії в цих тканинах [2]. Гістопатологічні особливості дифтерійного міокардиту наразі вивчалися лише в під

час розтинів. Зразки розтину міокарда показали великі ділянки гіалінової дегенерації та некрозу міокарда разом з активним запаленням в інтерстиціальних просторах. Інфільтрати мононуклеарних клітин з еозинофільною цитоплазмою також виявляються в цих ділянках. Флуоресцентне фарбування зрізів тканин антитілами демонструє дифтерійний токсин у плямистому розподілі в міокардальних волокнах, що може пояснити роль токсину в опосередкуванні пошкодження міокарда. Електронна мікрографія показує вражаючі ультраструктурні зміни в уражених міофібрилах, переважно за участю мітохондрій, які виглядають набряклими з втратою матриксу та дезорганізованими кристами, що також пов'язано з виснаженням глікогену та накопиченням ліпідних крапель. Процес міокардиту також залучає серцеву провідну тканину та призводить до спектру електрокардіографічних змін. Майже у половині пацієнтів з дифтерійним міокардитом розвиваються тяжкі порушення провідності, найсерйознішим з яких є повна синоатріальна блокада серця [1]. Натомість клапани, коронарні артерії, епікард та ендокард зазвичай не уражаються [9].

Висновок: Дифтерійний міокардит залишається одним із найнебезпечніших ускладнень дифтерії та основною причиною летальних наслідків при цьому захворюванні. Токсичне ураження міокарда за рахунок дії дифтерійного екзотоксину на кардіоміоцити характеризується поліморфізмом клінічних проявів, схильністю до швидкого прогресування та високим ризиком розвитку тяжких порушень серцевого ритму.

Список літератури:

1. Arvind B, Ojha V, Arava SK, Seth S, Ramakrishnan S. Diphtheritic myocarditis: An unusual and reversible cause of heart failure. *Ann Pediatr Cardiol.* 2022 May-Jun;15(3):311-313. doi: 10.4103/apc.apc_144_21. Epub 2022 Nov 16. PMID: 36589640; PMCID: PMC9802625.
2. Chanh HQ, Trieu HT, Vuong HNT, Hung TK, Phan TQ, Campbell J, Pley C, Yacoub S. Novel Clinical Monitoring Approaches for Reemergence of Diphtheria Myocarditis, Vietnam. *Emerg Infect Dis.* 2022 Feb;28(2):282-290. doi: 10.3201/eid2802.210555. PMID: 35075995; PMCID: PMC8798685.
3. Tyler R Jr, Rincon L, Weigand MR, Xiaoli L, Acosta AM, Kurien D, Ju H, Lingsweiler S, Prot EY. Toxigenic *Corynebacterium diphtheriae* Infection in Cat, Texas, USA. *Emerg Infect Dis.* 2022 Aug;28(8):1686-1688. doi: 10.3201/eid2808.220018. PMID: 35876749; PMCID: PMC9328917.
4. Truelove SA, Keegan LT, Moss WJ, Chaisson LH, Macher E, Azman AS, Lessler J. Clinical and Epidemiological Aspects of Diphtheria: A Systematic Review and Pooled Analysis. *Clin Infect Dis.* 2020 Jun 24;71(1):89-97. doi: 10.1093/cid/ciz808. PMID: 31425581; PMCID: PMC7312233.
5. Naidoo K, Msimang M, du Plessis M, Naidoo DP. Diphtheritic myocarditis: a case report, with toxin-mediated complications and multi-organ involvement. *Cardiovasc J Afr.* 2023 May-Jun 23;34(2):117-

120. doi: 10.5830/CVJA-2022-032. Epub 2022 Sep 5. PMID: 36063382; PMCID: PMC10512040.

6. Singh S, Gupta N, Saple P. Diphtheritic myocarditis: A case series and review of literature. *J Family Med Prim Care*. 2020 Nov 30;9(11):5769-5771. doi: 10.4103/jfmpc.jfmpc_1396_20. PMID: 33532430; PMCID: PMC7842443.

7. Ilyas S, Khan I, Yousafzai ZA, Kamran Amin Q, Rahman Z, Bilal M. Diphtheria-Associated Myocarditis: Clinical Profiles and Mortality Trends in a Tertiary Care Hospital in Pakistan. *Cureus*. 2024 Mar 22;16(3):e56744. doi: 10.7759/cureus.56744. PMID: 38650814; PMCID: PMC11033218.

8. du Plessis M, Mikhari R, de Gouveia L, Duma N, Lovelock T, Lawrence C, Mahabeer P, Mahabeer Y, Govender N, Nzenze S, Featherston J, Moodley M,

Moyes J, Walaza S, Cohen C, von Gottberg A. *Corynebacterium diphtheriae* Infections, South Africa, 2015-2023. *Emerg Infect Dis*. 2025 Mar;31(3):417-426. doi: 10.3201/eid3103.241211. PMID: 40023798; PMCID: PMC11878320.

9. Maghrabi K. Temporary Transvenous Pacemaker for the Treatment of Diphtheria Myocarditis and Progressive Conduction Block: A Case Report. *Cureus*. 2024 Jul 27;16(7):e65508. doi: 10.7759/cureus.65508. PMID: 39071066; PMCID: PMC11282894.

10. Poudel B, Lamsal A, Poudel CM. High mortality diphtheritic myocarditis with conduction disturbance, case series, and review of literature. *Ann Med Surg (Lond)*. 2023 Jul 3;85(8):3797-3800. doi: 10.1097/MS9.0000000000001037. PMID: 37554864; PMCID: PMC10406067.

PEDAGOGICAL SCIENCES

Abdullajonova Mushtariy

*Namangan State University of Foreign Languages,
Faculty of Philology Fourth-year student in Philology and
Language Teaching (English),*

E-mail: abdullajonovamushtariy79@gmail.com

*Namangan State University of Foreign Languages,
Faculty of Philology, Scientific supervisor:*

Madmusayev Jaxongir Muxtorali o'g'li

PhD (Pedagogical Sciences), Associate Professor,

Department of English Language and Literature

E-mail: madmusayevjahongir@gmail.com

ORCID: 0009-0006-0914-0319

THE GENERAL CLASSIFICATION OF CONNECTED SPEECH

Abstract.

This article provides a comprehensive analysis of connected speech within the framework of phonetics and phonology. The study focuses on systematic phonetic modifications that arise in continuous speech as a result of the interaction between adjacent sounds. Particular attention is given to such processes as assimilation, elision, linking, intrusion, and weak forms, examining their linguistic nature, underlying mechanisms, and functional roles in spoken communication. Furthermore, the article explores the relationship between these processes and key principles such as articulatory economy, speech efficiency, and communicative effectiveness. Connected speech is also analyzed in relation to prosodic and rhythmic features, emphasizing its role in shaping natural speech patterns. The findings of the study highlight the significant importance of connected speech in language acquisition and teaching, particularly in developing pronunciation accuracy and listening comprehension skills.

Keywords: *connected speech, assimilation, elision, linking, intrusion, weak forms, phonetics, phonology, prosody, pronunciation*

INTRODUCTION

In contemporary linguistics, spoken language is increasingly understood as a complex, dynamic, and continuously evolving system rather than a simple sequence of discrete and independent units. Traditional approaches often focused on isolated words and their standard pronunciation forms; however, modern phonetic and phonological studies emphasize that real-life speech is inherently connected and context-dependent. This continuous flow of speech, known as connected speech, represents one of the most significant features distinguishing natural spoken language from its written counterpart. Connected speech is characterized by the interaction of sounds across word boundaries, resulting in various phonetic modifications that alter the surface realization of speech without changing its semantic content. These modifications arise due to the articulatory, acoustic, and perceptual constraints inherent in human speech production. In spontaneous communication, speakers do not produce words in isolation; instead, they articulate them in a fluid sequence, where each sound is influenced by its phonetic environment. [1]

Consequently, the pronunciation of words in connected speech often differs significantly from their citation forms presented in dictionaries. From a theoretical perspective, the study of connected speech lies at the intersection of phonetics and phonology. Phonetics examines the physical properties of speech sounds, including their articulation and acoustic characteristics, while phonology investigates the abstract system and

patterns governing sound organization in a language. Connected speech processes provide a crucial link between these two domains, as they demonstrate how abstract phonological units are realized in actual speech under the influence of contextual factors. Therefore, analyzing connected speech allows linguists to better understand the relationship between underlying linguistic structures and their surface manifestations.

One of the fundamental principles underlying connected speech is the principle of articulatory economy, which suggests that speakers naturally tend to minimize effort while maintaining communicative efficiency. This principle leads to the simplification, reduction, or modification of certain sounds in order to facilitate smoother and faster speech production. As a result, a variety of phonetic processes emerge, including assimilation, elision, linking, intrusion, and the use of weak forms. These processes are systematic and rule-governed, reflecting the internal organization of the language rather than random variation.

Assimilation, for instance, demonstrates how adjacent sounds influence each other, often becoming more similar in place or manner of articulation. Elision illustrates the tendency to omit sounds that are difficult to articulate in rapid speech. Linking and intrusion ensure the continuity of speech by preventing hiatus between vowels, thereby contributing to the overall fluency of communication. Weak forms, on the other hand, highlight the role of stress and rhythm in spoken language, where function words are typically reduced

to maintain the natural prosodic pattern of English. Together, these processes form a coherent system that underpins the phonetic structure of connected speech. [2]

In addition to its production-related aspects, connected speech also plays a crucial role in speech perception. Listeners must be able to decode a continuous stream of sounds that often deviates from canonical forms. For native speakers, this process is largely automatic; however, for non-native learners, it can present significant challenges. The discrepancy between the forms taught in language classrooms and those encountered in authentic speech often leads to difficulties in listening comprehension. Therefore, an understanding of connected speech processes is essential for developing effective listening strategies and improving overall communicative competence. From a pedagogical standpoint, the incorporation of connected speech into language teaching is of paramount importance. Traditional teaching methods tend to prioritize grammar and vocabulary, often neglecting the phonetic dimension of language.

However, without adequate exposure to connected speech, learners may develop unnatural pronunciation patterns and struggle to understand fluent speech. By integrating the study of connected speech processes into pronunciation teaching, educators can help learners achieve greater fluency, intelligibility, and confidence in spoken communication. Moreover, connected speech is closely related to prosody, including stress, rhythm, and intonation, which play a vital role in conveying meaning and structuring discourse. The rhythmic pattern of English, often described as stress-timed, relies heavily on the alternation of stressed and unstressed syllables.

Weak forms and reductions contribute to this pattern, ensuring that speech maintains its characteristic tempo and flow. Thus, connected speech cannot be fully understood without considering its prosodic context. It is also important to note that connected speech processes may vary across different dialects and varieties of English. For example, the use of linking and intrusive /r/ is more prominent in British English, while certain reduction patterns may differ in American English. These variations highlight the adaptability and diversity of spoken language, further emphasizing the need for a comprehensive and systematic approach to the study of connected speech. [3]

In light of the above considerations, the present article aims to provide a general classification of connected speech processes, focusing on their linguistic nature, underlying mechanisms, and functional roles in spoken communication. By examining the main types of connected speech phenomena, this study seeks to contribute to a deeper understanding of how speech operates as an integrated and dynamic system, as well as to underline the importance of these processes in both theoretical linguistics and practical language teaching.

Systematic Classification of Connected Speech Processes

Connected speech represents a fundamental characteristic of natural spoken language, where linguistic units are not produced in isolation but as part of a continuous and dynamically organized speech stream. In real communicative situations, speakers do not consciously articulate each sound separately; instead, they produce speech in a fluid manner, allowing sounds to interact and influence one another. This interaction leads to systematic phonetic modifications that form the basis of connected speech processes. From a speech production perspective, these processes are closely linked to the physiological and cognitive mechanisms of articulation.

The human speech apparatus operates under time constraints and aims to achieve maximum efficiency with minimal effort. As a result, speakers naturally adjust their pronunciation depending on the surrounding phonetic context, speech rate, and communicative intention. These adjustments are not random but follow predictable patterns that can be classified into distinct categories. In connected speech, the flow of spoken language is shaped by three major factors: articulatory convenience, speech rhythm, and communicative efficiency. Articulatory convenience ensures that speech organs move smoothly from one sound to another. Speech rhythm organizes the temporal structure of utterances, particularly in stress-timed languages like English. [4]

Communicative efficiency guarantees that the message is conveyed clearly despite phonetic reductions. Together, these factors determine how connected speech processes operate in real-time communication. The general systemic classification of connected speech processes reflects these underlying principles and divides them into five main categories: modification, reduction, juncture, insertion, and prosodic processes. Each of these categories corresponds to a specific type of phonetic behavior observed in natural speech.

Importantly, these categories are interconnected and often occur simultaneously within a single utterance, demonstrating the integrative nature of spoken language. Connected speech is a multidimensional phonetic and phonological phenomenon that reflects the dynamic interaction of sounds within a continuous stream of speech. Unlike isolated word pronunciation, connected speech involves systematic modifications that arise due to coarticulation, prosodic structure, and communicative efficiency. These processes are governed by linguistic rules and can be classified into several categories based on their mechanism and function. From a theoretical standpoint, connected speech processes can be grouped into five major categories: modification, reduction, juncture, insertion, and prosodic processes. Each category represents a specific type of phonetic behavior that contributes to the naturalness and fluency of spoken language. This classification allows for a structured understanding of how speech operates as an integrated system.

Table 1

| Category | Process | Phonetic mechanism | Primary function | Level |
|------------------------|--------------|--|--------------------------------|-------------------|
| Modification processes | Assimilation | Sound adaptation to neighboring sounds | Articulatory ease | Segmental |
| Reduction processes | Elision | Omission of sound | Speech economy | Segmental |
| Juncture processes | linking | Connection between word boundaries | Continuity of speech | Boundary/Prosodic |
| Insertion processes | Intrusion | Addition of transitional sounds | Avoidance of hiatus | Boundary |
| Prosodic processes | Weak forms | Reduction of unstressed words | Rhythm and stress organization | Suprasegmental |

From the perspective of speech perception, these processes are equally important. While speakers produce connected speech unconsciously, listeners must decode a highly variable and often reduced speech signal. This requires the ability to recognize words even when their phonetic forms differ from standard dictionary pronunciations. Therefore, connected speech serves as a bridge between speech production and speech perception,

ensuring effective communication despite phonetic variability. Furthermore, connected speech processes are influenced by speech style and context. In careful or formal speech, these processes may be less pronounced, while in rapid or informal speech, they become more frequent and more noticeable. This variability highlights the adaptive nature of spoken language, where pronunciation changes according to communicative needs. [5]

Table 2.

Connected Speech in Different Speech Styles

| Speech Style | Characteristics | Connected Speech Activity |
|----------------|------------------------------|-----------------------------------|
| Careful speech | Characteristics | Minimal Reduction |
| Neutral speech | Normal conversational speed | Moderate processes |
| Rapid speech | Fast, informal communication | Strong reduction and assimilation |

In addition, connected speech processes can be viewed as part of a broader speech organization system, where segmental and suprasegmental features interact. Segmental processes (such as assimilation and elision) affect individual sounds, while suprasegmental features

(such as stress and rhythm) shape the overall structure of speech. The interaction between these levels creates a coherent and natural speech pattern that is characteristic of fluent speakers.

Table 3.

Multi-Level Nature of Connected Speech

| Level | Processes | Speech function |
|----------------|-----------------------|---------------------------|
| Segmental | Assimilation, Elision | Sound –level modification |
| Boundary | Linking, Intrusion | Word connection |
| Suprasegmental | Weak forms, rhythm | Speech timing and fluency |

Classification by Linguistic Levels and Speech Organization

Connected speech should be understood not as a collection of isolated phonetic processes, but as a multi-layered linguistic system that operates across different levels of language organization. In real speech, sounds are not produced independently; instead, they function within a complex structure where segmental, boundary, and suprasegmental elements interact continuously. This interaction reflects the dynamic nature of spoken language and highlights the importance of analyzing connected speech from a systemic perspective. At the most basic level, connected speech involves segmental processes, which affect individual sounds or phonemes.

These processes arise due to coarticulation, a phenomenon in which the articulation of one sound overlaps with that of adjacent sounds. As a result, phonetic

units are modified in accordance with their phonetic environment. Assimilation and elision are the most prominent examples of segmental processes, demonstrating how sounds adapt or disappear in order to facilitate smoother and more efficient speech production. These modifications are particularly noticeable in rapid or informal speech, where the need for articulatory economy is strongest. However, connected speech cannot be fully explained by segmental processes alone. Equally important are the boundary or juncture processes, which occur at the interface between words. In natural speech, speakers tend to avoid pauses between words, especially when this would disrupt the flow of communication. Consequently, linking and intrusion emerge as mechanisms that ensure continuity. Linking connects the final sound of one word to the initial sound of the

next, while intrusion introduces an additional sound to bridge two adjacent vowels. [6]

These processes contribute to the smoothness of speech and help maintain its rhythmic integrity. Beyond the level of individual sounds and word boundaries, connected speech is also shaped by suprasegmental features, including stress, rhythm, and intonation. These features operate over larger units of speech and play a crucial role in organizing the temporal structure of spoken language. In English, which is typically described as a stress-timed language, the distribution of stress determines the rhythm of speech. Weak forms, which involve the reduction of unstressed function words, are a direct manifestation of this prosodic organization.

By reducing less important elements, speakers allow stressed syllables to stand out, thereby preserving the natural rhythm and intelligibility of speech. Importantly, these linguistic levels do not function independently; rather, they interact in a highly integrated manner. For example, a segmental process such as assimilation may occur at a word boundary, while its realization is influenced by the stress pattern of the utterance. Similarly, the use of weak forms depends not only on the lexical category of a word but also on its position within the rhythmic structure of speech. This interplay demonstrates that connected speech is not merely a phonetic phenomenon but a reflection of the broader organization of language. From a speech-oriented perspective, the classification of connected speech by linguistic levels provides valuable insight into both speech production and speech perception. Speakers rely on these processes to produce fluent and efficient utterances, while listeners must decode a continuous and often reduced speech signal.

The ability to recognize words despite phonetic variation is a key component of communicative competence, particularly in a second language. Furthermore, the degree to which these processes occur is influenced by factors such as speech rate, formality, and communicative context. In careful speech, pronunciation tends to be closer to canonical forms, with fewer reductions and modifications. In contrast, rapid and informal speech is characterized by a higher frequency of connected speech processes, resulting in greater phonetic variability. This variability underscores the adaptive nature of spoken language and highlights the importance of contextual factors in shaping pronunciation. In conclusion, the classification of connected speech according to linguistic levels—segmental, boundary, and suprasegmental—provides a comprehensive framework for understanding how speech is organized and realized in natural communication. This approach reveals that connected speech is a highly structured and systematic phenomenon, governed by linguistic principles and shaped by the demands of real-time communication. [7]

Functional Classification of Connected Speech

In addition to structural and linguistic-level classifications, connected speech can also be analyzed from a functional perspective, which focuses on the roles that these processes play in real communication. From this point of view, connected speech is not merely a set of phonetic modifications, but a system of mechanisms

that serve specific purposes in speech production, perception, and interaction. These functions are closely related to the efficiency, clarity, and naturalness of spoken language. One of the primary functions of connected speech is articulatory simplification. Human speech production is constrained by physiological factors, including the movement and coordination of the speech organs. In order to produce speech efficiently, speakers naturally tend to reduce effort by modifying or omitting certain sounds. Processes such as assimilation and elision directly contribute to this function by minimizing articulatory complexity. For example, instead of producing each sound separately, speakers allow adjacent sounds to influence one another, thereby reducing the need for abrupt or difficult articulatory movements.

Another important function is rhythmic organization, which is particularly significant in languages like English that rely on a stress-timed rhythm. In such languages, the alternation between stressed and unstressed syllables creates a regular temporal pattern. Connected speech processes, especially the use of weak forms, play a crucial role in maintaining this rhythm. By reducing the prominence of function words, speakers ensure that content words carry the main stress, resulting in a more natural and balanced speech pattern. Without these reductions, speech would become overly rigid and lose its characteristic flow. Connected speech also fulfills a transitional or cohesive function, ensuring the smooth connection between words and phrases. Processes such as linking and intrusion prevent breaks or interruptions in the speech stream, allowing speakers to maintain continuity. This function is particularly important in fluent speech, where pauses between words are minimized. By creating seamless transitions, connected speech enhances the coherence of spoken discourse and facilitates listener comprehension.

From a cognitive perspective, connected speech contributes to processing efficiency for both speakers and listeners. For speakers, phonetic reduction reduces the cognitive and physical effort required for speech production. [8]

For listeners, familiarity with connected speech patterns allows for faster and more accurate decoding of the speech signal. Although reduced forms may initially seem more difficult to understand, they actually follow predictable patterns that experienced listeners can recognize automatically. Thus, connected speech supports efficient communication by optimizing both production and perception processes. Another key function of connected speech is its role in communicative effectiveness. Natural speech is not only about transmitting information but also about doing so in a way that is appropriate to the context and easily understood by the listener.

Connected speech processes help achieve this by making speech more fluid and less fragmented. In informal contexts, a higher degree of phonetic reduction may signal spontaneity and naturalness, while in formal contexts, more careful articulation may be used to ensure clarity. Therefore, the use of connected speech is closely linked to pragmatic and sociolinguistic factors. It is also important to consider the pedagogical function

of connected speech, particularly in the context of second language acquisition. Many language learners experience difficulties in understanding native speakers because they are not familiar with the reduced and modified forms that occur in connected speech. By studying these processes from a functional perspective, learners can develop a more realistic understanding of how language is used in practice.

This, in turn, improves both their listening comprehension and their ability to produce more natural-sounding speech. Furthermore, connected speech plays a role in discourse organization, as prosodic features such as stress and intonation help structure information within an utterance. For instance, stressed words often carry new or important information, while unstressed elements provide grammatical support. Connected speech processes reinforce this distinction by reducing less important elements and highlighting key information. In this way, they contribute not only to the phonetic structure of speech but also to its informational and communicative organization. In conclusion, the functional classification of connected speech demonstrates that these processes serve multiple and interconnected roles within spoken language. They facilitate articulation, maintain rhythm, ensure continuity, enhance cognitive efficiency, and support effective communication. By examining connected speech from a functional perspective, it becomes clear that these processes are essential for the natural operation of language and cannot be separated from the broader system of human communication.

Assimilation as a Core Process in Connected Speech

Assimilation is widely regarded as one of the most fundamental and systematic processes within connected speech, reflecting the natural tendency of adjacent sounds to influence one another during speech production. In continuous speech, sounds are not articulated in isolation; instead, they are produced in a coordinated and overlapping manner, a phenomenon known as coarticulation. Assimilation emerges as a direct consequence of this interaction, allowing speakers to achieve smoother transitions between sounds and greater articulatory efficiency. From a phonetic perspective, assimilation involves changes in specific articulatory features such as place of articulation, manner of articulation, and voicing. [9]

These changes occur when one sound becomes more similar to a neighboring sound, either partially or completely. Importantly, assimilation does not alter the semantic meaning of an utterance; rather, it affects only the phonetic realization of sounds. This demonstrates that assimilation operates at the level of speech performance, while the underlying phonological structure remains intact. In real speech, assimilation is highly context-dependent and varies according to factors such as speech rate, style, and level of formality. In careful or formal speech, assimilation may be less pronounced, as speakers tend to articulate sounds more clearly. However, in rapid and informal speech, assimilation becomes more frequent and more noticeable, contributing to the natural flow of communication.

For instance, phrases like “good boy” or “handbag” often exhibit assimilation, where certain sounds are modified to match neighboring ones, resulting in more fluid pronunciation. From a classificatory standpoint, assimilation can be analyzed in terms of its direction and scope. Directional classification distinguishes between regressive assimilation, where a following sound influences a preceding one, and progressive assimilation, where a preceding sound affects a following sound. Coalescent assimilation represents a more complex type, in which two adjacent sounds merge to form a new sound that shares features of both.

These types illustrate the dynamic and bidirectional nature of sound interaction in connected speech. Another important dimension of assimilation is the degree to which it occurs. Partial assimilation involves the modification of only one or two phonetic features, while complete assimilation results in one sound becoming identical to another. The degree of assimilation often depends on the strength of articulatory influence and the phonetic environment in which the sounds occur. This variability highlights the flexible and gradient nature of speech processes. From a functional perspective, assimilation serves several important roles in spoken communication. First, it contributes to articulatory economy, reducing the effort required to produce complex sound sequences. By allowing sounds to adapt to one another, speakers can minimize abrupt movements of the speech organs and maintain a more efficient articulatory pattern. Second, assimilation enhances the fluency and continuity of speech, ensuring that utterances are produced smoothly without unnecessary interruptions. Third, it supports communicative efficiency, enabling speakers to convey messages quickly while preserving intelligibility. [10]

In addition to its role in speech production, assimilation also has significant implications for speech perception. Listeners must be able to recognize words even when their phonetic forms differ from canonical pronunciations. This requires familiarity with common assimilation patterns and the ability to use contextual cues to interpret reduced or modified forms. For language learners, this can present a considerable challenge, as they may initially rely on dictionary forms that do not reflect real speech. Therefore, understanding assimilation is essential for developing both listening comprehension and pronunciation skills.

Furthermore, assimilation can be viewed as part of a broader system of phonological organization, where phonetic variation is governed by underlying rules and constraints. Rather than being random or irregular, assimilation follows predictable patterns that can be systematically described and analyzed. This reinforces the idea that connected speech is a structured and rule-governed phenomenon, deeply embedded in the linguistic system. In conclusion, assimilation represents a central mechanism of connected speech, illustrating how sounds interact and adapt within a continuous speech stream.

Its analysis provides valuable insights into the relationship between phonetic realization and phonological structure, as well as into the processes that underlie

natural speech production and perception. As such, assimilation occupies a key position in both theoretical linguistics and practical language learning, serving as a

bridge between abstract linguistic knowledge and real communicative use. [11]

| Type | Description | Example | Pronunciation |
|-------------|--|-----------|---------------|
| Regressive | Following sound effects previous sound | Good boy | /gʊb bɔɪ/ |
| Progressive | Previous sound effects following sound | Dogs | dɒgz/ |
| Coalescent | Two sounds merge into one | don't you | dəʊntʃu:/ |
| Partial | Sound changes partly | Bad boy | |

Linking and Intrusion as Boundary Processes in Connected Speech

Linking and intrusion are two closely related processes in connected speech that operate at word boundaries and play a crucial role in maintaining the continuity and fluency of spoken language. In natural speech, words are not produced separately with clear pauses between them; instead, they are connected into a smooth and uninterrupted speech stream. Linking and intrusion emerge as mechanisms that facilitate this continuity, ensuring that transitions between words are phonetically natural and articulatorily efficient. From a phonetic perspective, linking refers to the connection between the final sound of one word and the initial sound of the next.

This process typically occurs when a word ending in a consonant is followed by a word beginning with a vowel. In such cases, the final consonant is not released separately but is directly attached to the following vowel, creating a seamless transition. For example, the phrase “pick it up” is pronounced as /pɪkɪtʌp/, where the /k/ links smoothly with the vowel /ɪ/. This type of linking is essential for avoiding pauses that would otherwise disrupt the natural flow of speech. A special type of linking involves the use of linking /r/, which is characteristic of non-rhotic varieties of English, such as British English. In these accents, the /r/ sound is pronounced only when it occurs before a vowel, even if it is not pronounced in isolation. For instance, in the phrase “far away”, the /r/ appears as a linking sound: /fɑːr əweɪ/.

This phenomenon demonstrates how pronunciation can depend on the phonetic context rather than the spelling of words. Intrusion, on the other hand, involves the insertion of an additional sound between two vowels at word boundaries. Unlike linking, intrusive sounds are not present in the spelling of the words but are added to facilitate smoother articulation. The most common intrusive sounds in English are /r/, /j/, and /w/. For example, in the phrase “idea of”, speakers often insert an /r/, producing /aɪdɪər əv/. Similarly, in “I agree”, an intrusive /j/ may be added, resulting in /aɪ j əɡriː/. Both linking and intrusion can be explained by the need to avoid hiatus, which is the occurrence of two adjacent vowel sounds without an intervening consonant. [12]

Such sequences can be difficult to articulate and may disrupt the rhythm of speech. By introducing a consonant-like transition, speakers ensure that the speech stream remains smooth and continuous. This

highlights the importance of articulatory ease in shaping connected speech processes. From a functional perspective, linking and intrusion contribute significantly to the fluency and cohesion of speech. They enable speakers to produce longer stretches of speech without interruption, thereby enhancing communicative efficiency.

In addition, these processes support the prosodic organization of language by maintaining a regular rhythm and preventing unnatural breaks between words. In terms of speech perception, linking and intrusion play a crucial role in how listeners interpret continuous speech. Native speakers are typically able to recognize linked and intrusive forms without difficulty, as they are familiar with these patterns. However, for language learners, these processes can be confusing, as they may obscure word boundaries and make it harder to identify individual words. For example, a learner might perceive “pick it up” as a single word due to the linking of sounds.

Therefore, understanding these processes is essential for improving listening comprehension. It is also important to note that linking and intrusion are influenced by speech style and context. In formal or careful speech, these processes may be less pronounced, while in rapid or informal speech, they become more frequent and more noticeable. This variation reflects the adaptive nature of spoken language, where pronunciation changes depending on communicative needs. Furthermore, linking and intrusion illustrate the interaction between phonetic and phonological systems. While they are realized at the phonetic level, their occurrence is governed by phonological rules and constraints. [13]

This demonstrates that connected speech is not random but structured and rule-based. In conclusion, linking and intrusion are essential boundary processes in connected speech that ensure smooth transitions between words and contribute to the overall fluency of spoken language. They reflect the principles of articulatory economy and communicative efficiency, while also playing a significant role in speech perception. Their study provides valuable insights into the dynamic and interconnected nature of spoken language.

The Role of Connected Speech in Communication and Language Learning Connected speech is not merely a phonetic phenomenon, but a fundamental component of real spoken communication that reflects the dynamic and adaptive nature of language. Its processes—assimilation, elision, linking, intrusion, and weak forms—operate together to ensure that speech is

produced efficiently, perceived accurately, and interpreted meaningfully. Therefore, the role of connected speech extends beyond pronunciation and becomes essential in both communication and language acquisition. From a communicative perspective, connected speech contributes significantly to the fluency and naturalness of spoken language. In real-life interaction, speakers aim to convey their ideas quickly and smoothly, without unnecessary pauses or interruptions.

Connected speech processes allow them to achieve this by simplifying articulation and creating seamless transitions between words. As a result, speech becomes more continuous and rhythmically organized, which enhances overall communicative effectiveness. Another important role of connected speech is its contribution to speech economy and efficiency. By reducing or modifying sounds, speakers minimize the physical effort required for articulation. This is particularly important in spontaneous speech, where rapid production is necessary. For example, the use of weak forms and elision allows speakers to shorten less important elements, while maintaining the clarity of the message. Thus, connected speech supports the principle of maximum communicative output with minimal effort. [14]

Connected speech also plays a crucial role in speech perception and comprehension. For listeners, understanding natural speech involves decoding a continuous stream of sounds that often differs from canonical forms. Native speakers are generally able to process these variations automatically, relying on their knowledge of phonetic patterns and contextual cues. However, for language learners, this can present significant difficulties. The mismatch between dictionary pronunciation and real speech often leads to misunderstandings. Therefore, awareness of connected speech processes is essential for improving listening skills. From a pedagogical standpoint, connected speech is of great importance in language teaching and learning. Traditional approaches to language instruction tend to focus on grammar and vocabulary, often neglecting the phonetic dimension of language. As a result, learners may develop accurate grammatical knowledge but still struggle with pronunciation and listening comprehension. Incorporating connected speech into teaching practice helps learners bridge this gap by exposing them to authentic speech patterns and enabling them to produce more natural utterances.

CONCLUSION

In conclusion, connected speech plays a central role in both communication and language learning. It enhances fluency, supports efficient speech production, facilitates comprehension, and contributes to the natural rhythm of language. Its study provides valuable insights into how spoken language functions as a dynamic and integrated system. Therefore, connected speech should be considered an essential area of research in linguistics, as well as a key component of effective language teaching and learning.

In addition, connected speech contributes to the development of communicative competence, which includes not only linguistic knowledge but also the ability to use language appropriately in different contexts. By mastering connected speech, learners can improve their fluency, intelligibility, and confidence in speaking. They also become better equipped to understand native speakers in real-life situations, where speech is rarely slow or carefully articulated. Another important aspect of connected speech is its relationship with prosody, including stress, rhythm, and intonation.

These suprasegmental features play a key role in structuring information and conveying meaning in spoken language. Connected speech processes work together with prosody to create a balanced and coherent speech pattern. For example, weak forms help maintain the rhythm of English, while linking and intrusion support smooth transitions between words. This interaction highlights the integrated nature of speech organization. Furthermore, connected speech is influenced by contextual and sociolinguistic factors, such as formality, speech style, and speaker identity. In formal contexts, speakers may use more careful pronunciation with fewer reductions, while in informal settings, connected speech processes become more prominent. This variation reflects the flexibility of language and its ability to adapt to different communicative situations.

Understanding these variations is essential for developing pragmatic competence. In conclusion, connected speech plays a central role in both communication and language learning. It enhances fluency, supports efficient speech production, facilitates comprehension, and contributes to the natural rhythm of language. Its study provides valuable insights into how spoken language functions as a dynamic and integrated system. Therefore, connected speech should be considered an essential area of research in linguistics, as well as a key component of effective language teaching and learning.

References

1. Roach, P. (2009). *English Phonetics and Phonology*.
2. Gimson, A. (2014). *Pronunciation of English*.
3. Crystal, D. (2008). *Dictionary of Linguistics*.
4. Kelly, G. (2000). *How to Teach Pronunciation*.
5. Underhill, A. (2005). *Sound Foundations*.
6. Carr, P. (2013). *English Phonetics and Phonology*.
7. Ashby, P. (2011). *Understanding Phonetics*.
8. Ladefoged, P. (2015). *A Course in Phonetics*.
9. Yule, G. (2010). *The Study of Language*.
10. Celce-Murcia, M. (2010). *Teaching Pronunciation*.
11. Jones, D. (2011). *English Pronouncing Dictionary*.
12. Wells, J. (2006). *English Intonation*.
13. Brown, G. (1990). *Listening to Spoken English*.
14. Tench, P. (2011). *Transcribing the Sound of English*.

THEORETICAL AND METHODOLOGICAL FOUNDATIONS OF DEVELOPING STUDENTS' WRITING AND SPEAKING SKILLS THROUGH A METACOGNITIVE APPROACH

Abstract:

This paper examines the theoretical and methodological foundations of developing students' writing and speaking skills through the metacognitive approach, which emphasizes awareness, control, and regulation of one's own learning processes. Drawing on socio-constructivist and cognitive theories, the study explores how metacognitive strategies such as planning, monitoring, and evaluating contribute to effective language production. The research highlights the necessity of integrating metacognitive instruction into language education to foster autonomous, reflective, and communicatively competent learners.

Keywords: metacognition, writing skills, speaking skills, language education, reflection, self-regulation, awareness, methodology, communicative competence.

INTRODUCTION

The development of writing and speaking skills remains a central concern in modern language pedagogy, especially in multilingual educational environments such as those in Central Asia. Traditional approaches to language learning often emphasize grammatical accuracy and vocabulary acquisition, yet overlook the cognitive and metacognitive dimensions that enable learners to consciously plan, monitor, and evaluate their communicative performance. In recent years, educational researchers have increasingly recognized the significance of metacognitive strategies—those that involve learners' awareness and regulation of their cognitive processes—in fostering meaningful language production and comprehension.

Metacognition, as defined by Flavell[1], refers to “knowledge and cognition about cognitive phenomena,” which includes both awareness of one's learning processes and the ability to regulate them. In the context of language education, metacognitive approaches facilitate the transformation of students from passive recipients of information into active, reflective participants in the learning process. They provide tools for learners to independently assess their progress, identify communication difficulties, and apply adaptive strategies for improvement. The metacognitive framework aligns closely with the communicative and competency-based paradigms promoted by UNESCO[27] and the OECD[26], which stress the importance of lifelong learning skills, self-directed learning, and critical reflection. Therefore, the present article aims to explore the theoretical underpinnings and methodological applications of the metacognitive approach in the development of writing and speaking skills among university students, proposing practical insights for educators and curriculum designers.

METHODS

The methodological foundation of this research is based on a theoretical-analytical and comparative approach, drawing from existing literature, cognitive psychology, and pedagogical models. The study synthesizes data from scientific publications (2015-2025), meta-analyses of language pedagogy, and empirical studies conducted in higher education contexts. It adopts a qualitative interpretive framework to identify

how metacognitive instruction affects the development of writing and speaking competencies.

The analysis focuses on three key methodological components:

1. Identification of metacognitive strategies applicable to writing and oral communication;
2. Evaluation of instructional models that integrate metacognition into communicative activities;
3. Assessment of theoretical congruence between metacognitive frameworks and language-learning outcomes.
4. The selected sources include works by Vygotsky, Oxford, Wenden, Schraw, Zimmerman, and contemporary Uzbek scholars emphasizing reflective and self-regulated learning.

LITERATURE REVIEW

The notion of metacognition—“thinking about thinking”—was first systematically articulated by John Flavell[1], who defined it as knowledge about and regulation of one's cognitive processes. Since its emergence, this construct has evolved into a cornerstone of educational psychology, language pedagogy, and self-regulated learning. Flavell distinguished between metacognitive knowledge (awareness of one's cognitive strategies, tasks, and self) and metacognitive regulation (planning, monitoring, and evaluating cognitive performance). His early research revealed that learners who consciously reflected on their thinking achieved higher problem-solving success, an idea that deeply influenced language education.

Subsequent decades witnessed the integration of metacognitive principles into various educational paradigms. Anderson[9] emphasized that in language learning, metacognition empowers students to become “conscious managers of their own comprehension and production.” Oxford[10], in her taxonomy of language learning strategies, positioned metacognitive strategies as the most critical for autonomous learning, comprising planning for learning, monitoring progress, and evaluating outcomes. Wenden[22] and O'Malley and Chamot[12] further operationalized these strategies in communicative contexts, suggesting that metacognitive awareness underlies learners' capacity to control speaking and writing processes consciously.

In Uzbekistan and Central Asia, the adoption of metacognitive frameworks has aligned with the competency-based and reflective paradigms endorsed by international agencies. Local scholars such as Abdulayev and Azizova [28,29] have expanded this theoretical base, interpreting metacognition as an essential condition for the development of self-directed, reflective learners in multilingual environments. This orientation corresponds to the post-Soviet pedagogical transition toward learner autonomy and constructivist methodology.

Moreover, Piaget's [4] cognitive developmental theory contributes to understanding the emergence of metacognition in adolescence and adulthood. He viewed reflective abstraction—the capacity to think about one's own thought processes—as the highest level of cognitive development. Thus, integrating metacognitive training in tertiary education supports the transition from surface learning to deep, reflective learning—a principle corroborated by the Constructivist Learning Theory [5], which regards learners as active constructors of meaning.

Writing, as both a cognitive and linguistic activity, demands complex integration of planning, drafting, monitoring, and revising. Bereiter and Scardamalia (1987) proposed a cognitive model distinguishing between “knowledge-telling” and “knowledge-transforming” strategies, with the latter reflecting metacognitive awareness. Metacognitive writers are able to consciously regulate their composing process, set rhetorical goals, and evaluate textual coherence and reader impact. Anderson and Graham [16,9] demonstrated empirically that explicit metacognitive instruction—teaching students to plan content, monitor language use, and self-evaluate—enhances textual organization and argumentation quality. In ESL/EFL contexts, metacognitive scaffolding (e.g., reflective journals, think-aloud protocols, self-assessment rubrics) improves both fluency and accuracy. Wenden [11] identified that learners who systematically apply planning and evaluation strategies produce more cohesive and contextually appropriate texts.

Recent studies by Uzbek researchers confirm these findings, showing that when university students engage in reflective writing cycles (planning - drafting - peer feedback - revision - reflection), their analytical and critical thinking abilities substantially improve. These scholars emphasize that metacognitive writing practices correspond with the Bloom's Revised Taxonomy [23] facilitating transitions from remembering and understanding to analyzing and creating.

Moreover, digital metacognitive tools—such as online portfolios, writing blogs, and AI-based text analyzers—enhance self-regulation in writing instruction. In the Uzbek EFL context, hybrid learning environments employing such tools support the development of functional literacy and critical discourse awareness.

Speaking requires immediate cognitive processing, where metacognitive control plays an equally crucial role. Goh and Taib [14] proposed the Metacognitive Awareness Listening and Speaking Framework, emphasizing the phases of planning (goal-setting, task

analysis), monitoring (self-observation, error detection), and evaluating (self-correction, feedback incorporation).

Learners who internalize metacognitive speaking strategies demonstrate higher speech fluency and coherence, as they can consciously monitor lexical choice, syntactic structure, and pragmatic appropriateness. Chamot [13] and Vandergriff [22] found that metacognitive awareness enhances listening and speaking comprehension, as learners reflect on what they understood, why misunderstandings occurred, and how to repair communication breakdowns.

In multilingual Uzbek classrooms, where Russian and English function as second and foreign languages, metacognitive approaches to speaking are vital. They encourage students to shift from rote memorization toward strategic oral expression, incorporating self-evaluation and peer feedback. Recent pedagogical experiments [28,36] demonstrated that using “reflection cards” and “self-assessment checklists” during oral tasks significantly improves pronunciation accuracy and discourse management.

Furthermore, collaborative metacognition—joint reflection among peers—facilitates higher-order thinking and collective regulation. Mercer and Donohoo [17,18] described this process as “intermental development,” where learners co-construct knowledge through dialogic reasoning. Such collaboration aligns with the *Kolaborativ yondashuv* (collaborative approach) promoted in Uzbek pedagogical research, linking metacognition with socio-interactive competence.

Metacognition is often conceptualized as the central component of self-regulated learning (SRL). Zimmerman [6] defined SRL as a process through which learners activate and sustain cognitions, behaviors, and affects to achieve learning goals. His cyclical model—comprising forethought (goal-setting and planning), performance (self-monitoring), and self-reflection (evaluation and adaptation)—mirrors the structure of metacognitive regulation.

Schraw and Moshman [7] proposed that metacognition and SRL share common mechanisms of cognitive control but differ in scope: SRL encompasses motivational and emotional regulation, while metacognition focuses primarily on cognitive awareness. Nevertheless, both constructs converge in the context of communicative skill development, where successful learners plan linguistic choices, monitor discourse, and evaluate communicative outcomes.

In applied linguistics, research by Teng and Zhang [21] has demonstrated that explicit SRL training embedded with metacognitive components significantly improves oral and written performance. Similarly, in Uzbek higher education, Mirzayeva [37] reported that SRL-based EFL programs promote learner autonomy and reflective reasoning, which are crucial for academic literacy and professional competence.

Despite extensive theoretical support, practical implementation of metacognitive approaches faces several challenges. Firstly, teachers often lack training in facilitating reflection and self-assessment, relying instead on traditional knowledge-transmission meth-

ods[10]. Secondly, students accustomed to teacher-centered instruction may resist assuming responsibility for their own learning. As noted by Uzbek researcher Qodirova[33] fostering metacognitive awareness requires gradual cultural adaptation within classrooms where hierarchical teacher-student relationships prevail.

Technological integration presents both opportunities and obstacles. Digital learning environments offer rich platforms for metacognitive engagement (e.g., e-portfolios, self-tracking dashboards), yet they require digital literacy and critical thinking skills that are unevenly distributed among learners. Nonetheless, research in Uzbek universities[34] demonstrates that blended learning combined with reflective practice fosters self-monitoring and metacognitive dialogue among students.

Synthesizing the literature reveals several convergent insights:

1. Cognitive and social interactionist theories (Vygotsky, Bandura, Bruner) provide the philosophical basis for metacognitive instruction, emphasizing internalization and self-regulation through interaction and reflection.

2. Empirical models (CALLA, SRSD, TLF) operationalize these theories into pedagogical practices that cultivate learners' capacity to manage their own communicative performance.

3. Cross-disciplinary research-linking metacognition with neuroeducation and digital pedagogy-highlights the adaptive potential of reflective learning in the 21st century.

4. Overall, the literature underscores that metacognitive instruction is not a supplementary technique but a transformational paradigm in education. It re-frames teaching as guidance for self-awareness and learning as an active process of meaning-making.

In the context of Uzbekistan's ongoing educational modernization, the metacognitive approach assumes special significance. National strategies prioritize competency-based learning, functional literacy, and reflective practice[38,39]. Within this framework, developing students' writing and speaking skills through metacognition fosters not only linguistic proficiency but also cognitive independence and socio-emotional maturity.

Uzbek researchers[28,29,30] emphasize that the metacognitive paradigm bridges traditional didacticism with innovative pedagogy. It aligns with Islamic and humanistic educational values that regard self-knowledge (*ma'rifat*) as the foundation of learning. By training students to think about their thinking, educators nurture reflective citizens capable of contributing to the nation's intellectual and cultural development.

In applied methodology, metacognitive training can be embedded in:

1. Pre-task planning (goal setting and prediction),
2. During-task monitoring (self-correction and peer dialogue), and
3. Post-task reflection (self-evaluation and portfolio compilation).

DISCUSSION

The synthesis of theoretical and empirical evidence presented in the literature reveals that the metacognitive approach is not merely a supplemental strategy but a fundamental paradigm for effective language instruction. When applied to writing and speaking development, metacognitive pedagogy reshapes the learner's role from that of a passive receiver of information to an autonomous, reflective participant. The capacity to consciously plan, monitor, and evaluate one's linguistic performance is directly linked to improved communicative competence and cognitive flexibility.

A key insight derived from Vygotsky's socio-constructivist theory is that metacognitive development is inherently social. Through guided interaction and collaborative reflection, learners internalize strategies that later become part of their independent practice. In practical terms, this means that classroom environments promoting dialogue, peer feedback, and shared problem-solving serve as optimal conditions for metacognitive growth.

Traditional writing instruction in many post-Soviet systems, including Uzbekistan, has been largely product-oriented, focusing on grammatical correctness and textual structure. The metacognitive perspective, however, advocates a process-oriented approach, where learners engage in iterative cycles of planning, drafting, revising, and reflecting. Each phase involves specific metacognitive operations that enhance both linguistic accuracy and conceptual depth.

At the planning stage, students activate prior knowledge, define communicative goals, and anticipate possible challenges. This stage encourages higher-order thinking consistent with Bloom's cognitive taxonomy-especially the levels of analysis and synthesis. During the drafting process, metacognitive monitoring ensures that writers stay aligned with their rhetorical objectives, checking coherence, argumentation, and lexical appropriateness. Finally, self-evaluation after drafting allows learners to identify strengths and areas for improvement, consolidating self-regulated learning habits.

Research conducted by Graham and Harris and Aytjanova[16,30] provides strong empirical support for this recursive model. Students trained to use reflective journals and self-assessment rubrics produced significantly higher-quality academic texts. Moreover, these practices enhance learners' metalinguistic awareness, enabling them to view writing as a form of cognitive problem-solving rather than mechanical reproduction.

In the Uzbek tertiary education environment, instructors can operationalize this model by integrating explicit metacognitive tasks into writing courses:

1. Pre-writing logs, where students articulate their objectives and strategies;
2. Peer feedback cycles, allowing learners to externalize and compare thought processes;
3. Post-writing reflections, assessing personal progress and strategic effectiveness.

Such reflective documentation transforms writing into a deliberate act of intellectual self-regulation.

The metacognitive approach also redefines oral communication as a consciously regulated cognitive

process. Speaking involves rapid decision-making and real-time monitoring-conditions under which metacognitive control plays a decisive role. Learners who develop awareness of their communicative intentions and linguistic choices can adapt their speech dynamically to context and audience.

Chamot (2004) and Goh (2018) have shown that teaching students to plan their discourse, anticipate potential misunderstandings, and self-correct during interaction enhances both fluency and accuracy. In Uzbek universities, where students frequently experience linguistic anxiety in English communication, this metacognitive scaffolding also contributes to psychological resilience and confidence.

Effective classroom practices for metacognitive speaking development may include:

1. Think-aloud dialogues, where learners verbalize their reasoning before responding;
2. Self-recorded speech analyses, allowing them to monitor progress over time;
3. "Reflection cards" or checklists, encouraging self-assessment after each oral task;
4. Peer reflection sessions, where metacognitive strategies are exchanged and co-evaluated.

These techniques correspond with Bandura's concept of self-efficacy: learners who observe evidence of their improvement are more likely to persist and engage. Thus, metacognition not only enhances linguistic skills but also strengthens motivational and emotional dimensions of communication.

Among innovative models emerging from Uzbek pedagogical research, the Triadic Learning Framework (TLF) represents a significant contribution to the integration of metacognition in education. Structured around three interrelated phases-analysis, prediction, and reflection-TLF operationalizes the cognitive mechanisms[31]

In the analysis phase, learners examine linguistic problems or communication scenarios, identifying key patterns and potential difficulties. The prediction phase involves setting goals and anticipating outcomes-a metacognitive act of forward planning. Finally, the reflection phase promotes self-evaluation, encouraging learners to compare actual results with intended goals and to plan adjustments for future performance.

Empirical validation of the TLF model Jo'razoda[31] in 5th-grade and university contexts demonstrates its effectiveness in improving analytical thinking, self-correction, and cooperative learning. The model's adaptability to both primary and tertiary education levels suggests its potential as a universal metacognitive scaffold. In higher education, integrating TLF into writing and speaking courses could involve project-based assignments where students conduct micro-research, predict communicative challenges, and reflect on their performance outcomes. Such iterative reflection cycles correspond with Kolb's[19] experiential learning model, reinforcing the continuity between experience, reflection, conceptualization, and application.

Implementing metacognitive pedagogy demands a transformation of the instructor's role from knowledge transmitter to facilitator of reflection. Teachers guide

learners in recognizing their thought processes, verbalizing strategies, and applying them autonomously. This aligns with Schön's[20] notion of the reflective practitioner, where the teacher models metacognitive behaviors through open dialogue, feedback, and modeling of self-questioning techniques.

In Uzbekistan's teacher education programs, this shift entails systematic professional development focusing on reflective teaching, diagnostic assessment, and learner autonomy. Courses on metacognitive pedagogy should train teachers to design activities that stimulate awareness rather than passive repetition. The inclusion of reflective portfolios, lesson debriefings, and collaborative peer observation in teacher training can institutionalize reflective culture within universities.

The 21st-century classroom increasingly integrates digital tools that extend metacognitive engagement beyond physical spaces. Online writing platforms, self-assessment applications, and collaborative discussion forums facilitate continuous reflection and feedback. Anderson[9] and Teng[21] highlight that digital environments provide authentic opportunities for learners to plan, monitor, and evaluate their linguistic output in real time.

In Uzbekistan, the gradual digitalization of higher education under national strategies offers fertile ground for digital metacognition. Tools such as Google Docs, Padlet, or Edmodo can be used to document metacognitive cycles-students plan their writing, receive asynchronous peer comments, and reflect through revision histories. Similarly, video-conferencing platforms enable reflective speaking practices where learners record, replay, and analyze their interactions.

The challenge lies in ensuring that technology serves as a medium for reflection rather than distraction. To achieve this, instructors must explicitly guide students in using digital platforms for cognitive self-regulation-setting learning goals, tracking progress, and assessing outcomes. Integration of digital portfolios, where students compile written and oral artifacts alongside reflective annotations, has proven particularly effective in fostering metacognitive literacy.

Metacognition, though universal in principle, manifests differently across cultural and educational contexts. In Uzbek culture, where collectivism and respect for authority traditionally shape classroom interaction, the introduction of self-regulated learning must be approached sensitively. Rather than positioning autonomy as independence from teachers, educators should frame it as responsible self-reflection within collaboration.

As Yuldasheva[34] observes, students in Uzbekistan often equate success with conformity to teacher expectations. Metacognitive instruction thus needs to reconcile reflective independence with social interdependence. The use of kolaborativ yondashuv (collaborative approach) supports this balance by linking personal reflection with peer dialogue. Group-based reflective activities-such as "double-entry journals" or "team reflection maps"-allow learners to share perspectives and co-construct understanding.

This collectivist-compatible metacognitive pedagogy also draws on indigenous concepts such as tafakkur (deep thought) and ma'rifat (self-knowledge), reinforcing the cultural continuity between traditional educational values and modern reflective practice. By aligning global theories with local epistemologies, Uzbek educators can indigenize metacognitive learning while maintaining scientific rigor.

Evaluating metacognitive development remains a complex yet essential component of effective pedagogy. Quantitative instruments such as the Metacognitive Awareness Inventory Schraw and Dennison[8], offer structured measurement, while qualitative tools capture nuanced reflections. In writing and speaking instruction, triangulating multiple sources-reflective journals, self-evaluation sheets, peer assessments, and teacher observations-yields a more comprehensive picture of progress.

The findings have important implications for curriculum design and educational policy in Uzbekistan. Embedding metacognitive instruction across disciplines can enhance not only linguistic proficiency but also general learning competence. Curriculum frameworks should therefore include explicit outcomes related to metacognitive skills-planning, monitoring, evaluating, and reflecting-as integral elements of communicative competence.

Teacher education institutions must develop modules on reflective teaching, cognitive psychology, and self-regulated learning. Moreover, policy directives should encourage universities to establish Centers for Reflective Pedagogy, providing methodological support and research resources. Such institutional structures would ensure the sustainability and scalability of metacognitive innovations.

In Uzbek universities, where the balance between tradition and modernization remains delicate, metacognitive pedagogy offers a bridge between inherited academic discipline and global innovation. By embedding cycles of reflection, prediction, and self-evaluation in language instruction, educators prepare students for lifelong learning in multilingual and multicultural environments. Thus, the theoretical and methodological foundations of metacognitive instruction reaffirm the central pedagogical truth articulated by Dewey[25]: "We do not learn from experience... we learn from reflecting on experience." In this light, reflection becomes not a final stage of learning but the very medium through which intellectual and communicative growth unfolds.

CONCLUSION

The comprehensive analysis conducted in this study substantiates the metacognitive approach as one of the most intellectually robust and pedagogically effective paradigms in modern language education. By uniting cognitive psychology, socio-constructivist theory, and reflective pedagogy, metacognition redefines the process of developing writing and speaking skills from mechanical reproduction to self-regulated intellectual performance. Learners consciously plan, monitor, and evaluate their communicative actions, thereby transforming language use into a domain of purposeful, reflective activity. This theoretical integration provides

the philosophical coherence necessary for modernizing foreign and second language teaching in Uzbekistan's higher education institutions.

Methodologically, the research highlights that metacognitive instruction facilitates a process-oriented and reflective approach to both writing and speaking. Writing becomes a recursive act of planning, drafting, revising, and reflecting, while speaking transforms into a consciously monitored interaction guided by self-assessment and peer collaboration. Instructors adopting this framework shift from the role of transmitters of knowledge to that of facilitators of metacognitive awareness, enabling learners to internalize strategies for autonomous learning and self-correction.

Empirical findings discussed in prior literature and local Uzbek research further validate that the implementation of reflective journals, self-assessment tools, and collaborative feedback mechanisms leads to measurable improvements in linguistic competence, coherence, and critical thinking. The Triadic Learning Framework[Ошибка! Источник ссылки не найден.], integrating the phases of analysis, prediction, and reflection, serves as a culturally adaptive model that harmonizes Western cognitive theory with Uzbek pedagogical traditions emphasizing collective reasoning (tafakkur) and moral-educational reflection (ma'rifat).

In conclusion, the metacognitive approach provides a powerful theoretical and methodological foundation for transforming language education in Uzbekistan. Its integration into curricula for writing and speaking ensures the formation of self-regulated, critically aware learners capable of navigating complex communicative and cognitive challenges. The pedagogical shift toward reflection, autonomy, and collaborative reasoning ultimately represents a transition from teaching languages to educating minds through language.

Reference list

1. Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive developmental inquiry. *American Psychologist*, 34(10), 906-911.
2. Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.
3. Bandura, A. (1986). *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, NJ: Prentice Hall.
4. Piaget, J. (1971). *Biology and Knowledge*. Chicago: University of Chicago Press.
5. Bruner, J. (1996). *The Culture of Education*. Cambridge, MA: Harvard University Press.
6. Zimmerman, B. J. (2002). Becoming a Self-Regulated Learner: An Overview. *Theory into Practice*, 41(2), 64-70.
7. Schraw, G., & Moshman, D. (1995). Metacognitive Theories. *Educational Psychology Review*, 7(4), 351-371.
8. Schraw, G., & Dennison, R. S. (1994). Assessing Metacognitive Awareness. *Contemporary Educational Psychology*, 19(4), 460-475.

9. Anderson, N. J. (2019). *Active Skills for Reading and Metacognitive Development in EFL Contexts*. London: Cengage Learning.
10. Oxford, R. L. (2017). *Teaching and Researching Language Learning Strategies: Self-Regulation in Context*. 2nd ed. New York: Routledge.
11. Wenden, A. (1998). Metacognitive Knowledge and Language Learning. *Applied Linguistics*, 19(4), 515-537.
12. O'Malley, J. M., & Chamot, A. U. (1994). *Learning Strategies in Second Language Acquisition*. Cambridge: Cambridge University Press.
13. Chamot, A. U. (2004). Issues in Language Learning Strategy Research and Teaching. *Electronic Journal of Foreign Language Teaching*, 1(1), 14-26.
14. Goh, C. C. M. (2018). *Teaching Listening and Speaking in Second Language Learning*. New York: Routledge.
15. Bereiter, C., & Scardamalia, M. (1987). *The Psychology of Written Composition*. Hillsdale, NJ: Lawrence Erlbaum Associates.
16. Graham, S. (2018). Theories and Practices of Writing Instruction: The Role of Metacognition. *Reading and Writing*, 31(6), 1339-1355.
17. Mercer, N. (2013). *The Social Brain and the Classroom*. London: Routledge.
18. Donohoo, J. (2018). *Collective Teacher Efficacy: Research to Practice*. Thousand Oaks, CA: Corwin Press.
19. Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development*. Englewood Cliffs, NJ: Prentice Hall.
20. Schön, D. A. (1983). *The Reflective Practitioner: How Professionals Think in Action*. New York: Basic Books.
21. Teng, F. (2021). *Metacognition in Language Learning and Teaching*. London: Routledge.
22. Vandergrift, L. (2007). Extensive Listening Practice and Input Enhancement Using Metacognitive Pedagogy. *Language Learning & Technology*, 11(2), 94-112.
23. Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. New York: Longman.
24. Bloom, B. S. (1976). *Human Characteristics and School Learning*. New York: McGraw-Hill.
25. Dewey, J. (2015). *Democracy and Education*. New York: Free Press.
26. OECD. (2022). *PISA 2022 Assessment and Analytical Framework*. Paris: OECD Publishing.
27. UNESCO. (2019). *Futures of Education: Learning to Become*. Paris: UNESCO Publishing.
28. Abdullayev, A'.A. (2023). Boshlang'ich sinf ona tili va o'qish savodxonligi darslarida o'quvchilarning regulativ ta'limiy faoliyatini shakllantirish texnologiyalari. *Ta'limning zamonaviy transformatsiyasi jurnali*, №3, 55-62.
29. Azizova, M. (2024). Refleksiv yondashuv asosida talabalarda metakognitiv kompetensiyani shakllantirish. *O'zbekiston Pedagogika Jurnal*, №2, 45-53.
30. Aytjanova, A. S. (2025). Talabalarda yozma nutqni rivojlantirishda metakognitiv yondashuv asosida refleksiv o'qitish metodikasi. Toshkent: TDPU nashriyoti.
31. https://scholar.google.ru/citations?view_op=view_citation&hl=ru&user=1d-I2-EAAAAJ&citation_for_view=1d-I2-EAAAAJ:ufrVoPGSRksC
32. Ismailova, Z. (2022). Metakognitiv yondashuvning xorijiy tillarni o'qitishda qo'llanishi. *Ta'lim texnologiyalari va innovatsiyalar jurnali*, №4, 71-78.
33. Qodirova, G. (2024). Oliy ta'limda refleksiv madaniyatni shakllantirishning pedagogik asoslari. *Namangan Davlat Universiteti ilmiy axboroti*, №1, 112-119.
34. Yuldasheva, D. (2023). Raqamli ta'lim muhitida metakognitiv strategiyalarni qo'llash samaradorligi. *Zamonaviy ta'lim jurnali*, №5, 88-96.
35. Abdullayeva, M. (2024). Og'zaki nutqni rivojlantirishda refleksiya kartalaridan foydalanishning metodik asoslari. *Til va adabiyot ta'limi jurnali*, №6, 34-41.
36. Tursunova, D. (2023). Talabalarda kommunikativ kompetensiyani shakllantirishda o'z-o'zini baholash texnologiyalari. *Pedagogika fanlari jurnali*, №2, 65-73.
37. Mirzayeva, N. (2023). Self-Regulated Learning asosida ingliz tili ta'limida mustaqil fikrlashni rivojlantirish. *Oliy ta'lim muammolari jurnali*, №7, 25-31.
38. PQ-5117. (2021). O'zbekiston Respublikasida 2030-yilgacha ta'lim sohasini rivojlantirish konsepsiyasini tasdiqlash to'g'risida. Toshkent: Prezident qarori.
39. PF-60. (2022). 2022-2026-yillarga mo'ljallangan Yangi O'zbekiston taraqqiyot strategiyasi. Toshkent: Prezident Farmoni.

YUQORI SINIF O'QUVCHILARIDA CEFRGA MOS YOZMA VA OG'ZAKI NUTQ
KO'NIKMALARINI RIVOJLANTIRISHDA DISCOURSE MARKERS VA CLAUSE
CONNECTORSLARNI O'QITISH METODIKASIMirjalol Ziyoviddinov Gafurjon oglu
NamDChTIMETHOD OF TEACHING DISCOURSE MARKERS AND CLAUSE CONNECTORS IN
DEVELOPING CEFR-COMPLIANT WRITING AND ORAL SPEECH SKILLS IN HIGHER-GRADE
STUDENTS**Annotatsiya.**

Ushbu maqolada O'zbekiston umumta'lim maktablari yuqori sinf o'quvchilarining ingliz tilida yozma va og'zaki nutq ko'nikmalarini rivojlantirishda discourse markers hamda clause connectorlarni o'qitishning metodik asoslari tadqiq etiladi. Tadqiqotning asosiy maqsadi CEFR B1–B2 talablari asosida o'quvchilarning coherence, cohesion, fluency va logical sequencing ko'nikmalarini rivojlantirishda bog'lovchi vositalarning rolini aniqlashdan iborat. Tadqiqotda sifat va miqdoriy yondashuvlar, tajriba-sinov darslari, pre-test/post-test, yozma ish va speaking performance tahlili qo'llanildi. Natijalar discourse markersni explicit o'qitish o'quvchilarning IELTS tipidagi writing va speaking topshiriqlarida fikrlarni izchil bayon qilish ko'rsatkichlarini sezilarli oshirishini ko'rsatdi. Discourse markers text coherence va oral fluency uchun markaziy vosita ekanligi aniqlandi.

Abstract.

This article investigates the methodological foundations of teaching discourse markers and clause connectors to improve CEFR-aligned writing and speaking skills among senior secondary school learners in Uzbekistan. The primary objective is to determine the role of cohesive devices in developing learners' coherence, cohesion, fluency, and logical sequencing within B1–B2 CEFR descriptors. The study employs mixed-method research, including quasi-experimental lessons, pre-test/post-test design, essay analysis, and oral performance assessment. Findings demonstrate that explicit instruction of discourse markers significantly improves learners' ability to organize ideas coherently in IELTS-style writing and speaking tasks. The study confirms that discourse markers function as central tools in improving textual cohesion and oral discourse fluency in EFL classrooms.

Kalit so'zlar: discourse markers, clause connectors, CEFR, writing coherence, speaking fluency, senior secondary school, EFL, cohesive devices

Keywords: discourse markers, clause connectors, CEFR, IELTS, cohesion, coherence, speaking fluency, secondary education

KIRISH

Bugungi global ta'lim makonida ingliz tilini kommunikativ va akademik maqsadlarda o'qitishda **grammatik kompetensiyadan discourse competencega o'tish** muhim metodik tamoyilga aylandi. Ayniqsa O'zbekiston maktablarining yuqori sinflarida o'quvchilarni xalqaro baholash tizimlariga tayyorlashda fikrlarni mantiqiy bog'lash vositalari alohida ahamiyatga ega.

Discourse markers hamda clause connectors ingliz tilini chet tili sifatida o'rganayotgan yuqori sinf o'quvchilarining yozma va og'zaki nutq kompetensiyasini rivojlantirishda muhim lingvodidaktik vositalardan biri hisoblanadi. Xususan, *however, therefore, moreover, in addition, on the other hand, as a result* kabi discourse markers hamda *because, although, while, if, unless, since* kabi clause connectors o'quvchilarga fikrlar o'rtasidagi mantiqiy munosabatlarni aniq ifodalash, sabab-oqibat, qarama-qarshilik, qo'shimcha ma'lumot, misol keltirish va xulosa chiqarish kabi nutq funksiyalarini bajarishda yordam beradi. Ushbu birliklar nafaqat grammatik to'g'rilikni, balki matnning yaxlitligi va mantiqiy izchilligini ham ta'minlaydi.

Yozma nutqda ular o'quvchilarning essay writing coherence va cohesion ko'rsatkichlarini sezilarli darajada oshiradi, paragraf ichidagi hamda paragraf oralig'idagi fikrlarning uzviy bog'lanishini ta'minlaydi. Og'zaki nutqda esa speaking fluency, idea sequencing, argument development va turn extension kabi ko'nikmalarni rivojlantirishda markaziy rol o'ynaydi. Ayniqsa, munozara, fikr bildirish, taqqoslash va sabablarni tushuntirishga asoslangan speaking topshiriqlarida discourse markerlar javobning tabiiyligi va davomiyligini kuchaytiradi.

CEFR B1–B2 deskriptorlariga ko'ra o'quvchi "connected speech" va "connected writing" yaratish, ya'ni fikrlarini mantiqan bog'langan holda yozma va og'zaki shaklda ifodalash qobiliyatiga ega bo'lishi lozim. Shu nuqtai nazardan, bog'lovchi diskurs birliklarini tizimli va bosqichma-bosqich o'qitish yuqori sinf ingliz tili metodikasining muhim tarkibiy qismi sifatida qaraladi.

TADQIQOT METODOLOGIYASI

Mazkur tadqiqot **quasi-experimental mixed-method design** asosida tashkil etildi. Tadqiqot Namanagan viloyatidagi ikki umumta'lim maktabining 10–11-sinf o'quvchilari ishtirokida olib borildi. Jami 60 nafar

o'quvchi tadqiqotga jalb qilinib, ular teng ravishda eksperimental va nazorat guruhlariga ajratildi. Har bir guruhda 30 nafardan o'quvchi bo'lib, ularning til bilish darajasi CEFR mezonlari asosida B1–B2 oralig'ida deb belgilandi¹.

Tadqiqot jarayonida o'quvchilarning dastlabki ko'rsatkichlarini aniqlash uchun diagnostik pre-test, IELTS uslubidagi essay writing topshiriqlari hamda speaking interviular qo'llanildi. Eksperimental guruhda discourse markers va clause connectorslarni eksplisit tarzda o'qitishga qaratilgan maxsus darslar tashkil etildi, nazorat guruhida esa an'anaviy grammatika o'qitish usullari davom ettirildi. Intervensiya yakunida post-test, classroom observation, error analysis va frequency analysis metodlari orqali natijalar qayta baholandi.

O'qitish intervensiyasi 6 haftalik maxsus modul asosida ishlab chiqildi. Modul davomida additive markers, contrastive markers, result markers, exemplification markers, cause-effect clauses, concession clauses, speaking fillers hamda turn organizers bosqichma-bosqich o'rgatildi. Mashg'ulotlarda *firstly, secondly, finally; however, nevertheless; because, since, therefore; although, even though; as a result; for example* kabi birliklardan yozma va og'zaki vazifalarda faol foydalanish mashq qilindi.

ADABIYOTLAR TAHLILI

Discourse markers bo'yicha olib borilgan zamonaviy ilmiy tadqiqotlar ularning textual cohesion va pragmatic organizationdagi o'rnini alohida ta'kidlaydi. Xususan, Deborah Schiffrin discourse markersni "discourse segmentsni chegaralovchi va ular orasidagi semantik-pragmatik munosabatlarni ko'rsatuvchi birliklar" sifatida tavsiflaydi. Ushbu ta'rif discourse markerlarning nafaqat grammatik, balki diskursiv funktsiya bajarishini ko'rsatadi².

Kapranov tadqiqotlarida discourse markerlarning speaking fluency va classroom interactionga ijobiy ta'siri aniqlangan bo'lib, ular ayniqsa o'quvchilarning javobni davom ettirish, fikrni kengaytirish va suhbat navbatini ushlab turish ko'nikmalarini rivojlantirishi qayd etiladi. Feng esa yozma ishlarda discourse markerlarning noto'g'ri yoki yetarli bo'lmagan qo'llanilishi coherence darajasining pasayishiga olib kelishini ta'kidlaydi³. Grade 12 o'quvchilari ustida olib borilgan empirik tadqiqotlar ham discourse marker proficiency academic writing sifatiga bevosita ta'sir ko'rsatishini isbotlagan.

CEFR frameworkga ko'ra B2 darajadagi o'quvchi turli linking words va cohesive deviceslardan samarali foydalanib, fikrlar orasidagi mantiqiy bog'liqlikni ko'rsatishi kerak. Mazkur talab aynan discourse marker competence bilan uzviy bog'liq bo'lib, yuqori sinf o'quvchilarida ushbu ko'nikmani shakllantirish dolzarb metodik vazifa hisoblanadi⁴.

MUHOKAMA VA NATIJALAR

Tajriba yakunlari discourse markers va clause connectorslarni eksplisit o'qitish sezilarli ijobiy natijalar berganini ko'rsatdi. Eksperimental guruh yozma ishlarida coherence ko'rsatkichi 31 foizga, cohesion 28 foizga, paragraph logic 35 foizga va idea progression 33 foizga oshgani kuzatildi. O'quvchilar, ayniqsa, *however, therefore, in contrast, as a result, for instance, although, despite this* kabi birliklarni fikrlarni bog'lashda faol qo'llay boshladilar⁵. Bu esa essaylarning mantiqiy tuzilishi, dalillarning izchilligi va xulosa qismlarining ravshanligiga ijobiy ta'sir ko'rsatdi.

Speaking topshiriqlarida ham sezilarli rivojlanish qayd etildi. O'quvchilarda hesitation kamaydi, response length uzaydi, idea extension yaxshilandi va fluency descriptor darajasi oshdi. Masalan, tajribadan oldin o'quvchi *"I like online learning. It is easy. Teachers help."* kabi qisqa va uzilgan gaplardan foydalangan bo'lsa, intervensiyadan so'ng *"I like online learning because it is flexible. Moreover, it allows students to access additional resources. However, it may reduce face-to-face communication."* kabi mantiqan bog'langan, kengaytirilgan javoblar bera boshladi. Mazkur natija CEFR B2 darajasidagi connected speech descriptorlariga to'liq mos keladi.

XULOSA

Tadqiqot natijalari shuni ko'rsatdiki, discourse markers va clause connectorsni eksplisit, CEFR-oriented yondashuv asosida o'qitish yuqori sinf o'quvchilarining writing va speaking ko'nikmalarini sezilarli rivojlantiradi.

Ayniqsa:

- ❖ IELTS Writing Task 2
- ❖ opinion essays
- ❖ discussion essays
- ❖ extended speaking responses
- ❖ classroom debates

uchun ushbu yondashuv juda samarali.

Maqola natijalari O'zbekiston maktablari ingliz tili darsliklarida **cohesive devices progression syllabus** yaratish zarurligini ko'rsatadi.

FOYDALANILGAN ADABIYOTLAR

1. Deborah Schiffrin (1987). *Discourse Markers*. Cambridge: Cambridge University Press.
2. Fraser, B. (1999). What are discourse markers? *Journal of Pragmatics*, 31(7), 931–952.
3. Biber, D. (2006). *University Language: A Corpus-Based Study*. London: Routledge.
4. Kapranov, O. (2020). The use of discourse markers in oral discourse in EFL classroom. *ONOMÁZEIN*.
5. Feng, L. (2010). Discourse markers in English writing. *Journal of Language Teaching and Research*.
6. Mumbi, C. M. (2017). Proficiency in the use of discourse markers in English composition writing.
7. CEFR Companion Volume (2020). *Council of Europe*.

¹ Deborah Schiffrin (1987). *Discourse Markers*. Cambridge: Cambridge University Press

² Fraser, B. (1999). What are discourse markers? *Journal of Pragmatics*, 31(7), 931–952

³ Hyland, K. (2004). *Genre and Second Language Writing*. Michigan: University of Michigan Press

⁴ Halliday, M. A. K., & Hasan, R. (1976). *Cohesion in English*. London: Longman.

⁵ Nation, I. S. P. (2009). *Teaching ESL/EFL Reading and Writing*. Routledge.

8. Halliday, M. A. K., & Hasan, R. (1976). *Cohesion in English*. London: Longman.

9. Hyland, K. (2004). *Genre and Second Language Writing*. Michigan: University of Michigan Press.

10. Nation, I. S. P. (2009). *Teaching ESL/EFL Reading and Writing*. Routledge.

Raximova Sarvinoz Abdug'ani qizi

NamSIFL,

Namangan, Uzbekistan

Madmusayev Jahongir Muxtorali o'g'li

Senior Lecturer, Department of English Language and Literature,

NamSIFL,

Namangan, Uzbekistan

THE FUNCTIONAL-COMMUNICATIVE ROLE OF FUNCTION WORDS IN ENGLISH SENTENCE STRUCTURE: A CORPUS-BASED AND CONTRASTIVE ANALYSIS

Abstract.

This article examines the role of function words in English sentence structure and explains why these grammatical units should be treated as an essential part of both sentence formation and communicative meaning. The study pays special attention to four major groups of function words—auxiliary verbs, modal verbs, prepositions, and conjunctions—because these elements occur regularly in natural English and play a more significant role in sentence construction than they are sometimes assumed to. Although function words usually do not carry strong independent lexical meaning, they are indispensable in forming grammatically complete, logically connected, and contextually appropriate utterances. In actual language use, they do more than simply support grammar in the background; in many cases, they directly influence how an idea is shaped, linked, and understood.

The research is based on the analysis of 2,500 sentence examples selected from the British National Corpus (BNC) and the Corpus of Contemporary American English (COCA). To examine the selected material, the study combines descriptive, functional-semantic, contrastive, and statistical methods. The results show that function words appear with high regularity in different types of authentic English discourse and should therefore be regarded not as secondary grammatical details, but as one of the central components of sentence organization. The findings also indicate that Uzbek learners of English often experience repeated difficulties in this area, mainly because English and Uzbek rely on different grammatical mechanisms to express similar meanings. For this reason, the article argues that function words should be taught not only through isolated grammar rules, but also through contextualized examples, authentic usage patterns, and contrastive explanation. Overall, the study supports a more communicative and practically oriented approach to grammar teaching in contexts where structural differences between the native language and English strongly affect learner performance.

Keywords: *function words, English sentence structure, auxiliary verbs, modal verbs, prepositions, conjunctions, corpus analysis, contrastive analysis, communicative role, English language teaching*

INTRODUCTION

In English sentence structure, function words play a much more important role than they are often given in ordinary grammar explanation. When students first learn English, most of their attention usually goes to content words such as nouns, main verbs, adjectives, and adverbs because these words seem to carry the main meaning of the sentence. However, real communication shows that lexical meaning alone is not enough. A sentence may contain the right vocabulary, but if the function words are missing, misused, or placed incorrectly, the utterance can become incomplete, unclear, unnatural, or even grammatically unacceptable. This is why function words deserve to be studied not as minor supporting elements, but as one of the central mechanisms of English sentence organization.

The relevance of this topic becomes even clearer when English is considered from a typological point of view. English is generally described as an analytic language, which means that many grammatical meanings are expressed through separate words rather than through rich inflectional endings. Because of this, function words become one of the main tools through which grammatical relations are built inside the sentence. Auxiliary verbs help form tense, aspect, negation, and

interrogation; modal verbs express possibility, necessity, probability, advice, and speaker attitude; prepositions establish spatial, temporal, causal, and abstract relations; conjunctions connect clauses and make logical links between ideas explicit. In this sense, function words are not simply technical grammatical markers. They directly affect how the speaker structures information and how the listener or reader interprets it.

From the perspective of language teaching, this issue is especially important. In many classrooms, learners often focus on vocabulary growth and pay less attention to grammatical words because such items may seem small, repetitive, or less meaningful at first sight. Yet classroom experience shows the opposite: many learner errors that make English sound unnatural are caused not by vocabulary shortage, but by inaccurate use of function words. This is particularly noticeable among Uzbek learners of English. Since Uzbek and English belong to different typological systems, similar meanings are often expressed in very different ways. English frequently depends on separate grammatical words, while Uzbek often uses suffixes or other structural devices. As a result, Uzbek-speaking learners may omit auxiliary verbs, overuse or confuse modal forms, choose unsuitable prepositions, or connect clauses in ways that reflect native-language patterns rather than natural English usage.

The present article aims to examine the role of function words in English sentence structure from both structural and communicative perspectives. Special attention is given to four major groups—auxiliary verbs, modal verbs, prepositions, and conjunctions—because these categories are especially frequent and functionally significant in authentic English. The study seeks to clarify how these units contribute to sentence formation, semantic interpretation, and discourse coherence. It also attempts to show why they should receive greater attention in English language teaching, especially in Uzbek-speaking learning environments. The research is based on sentence samples drawn from the British National Corpus (BNC) and the Corpus of Contemporary American English (COCA), and it combines descriptive, functional-semantic, contrastive, and statistical methods. The main argument of the article is that function words are not peripheral grammatical details, but active and indispensable components of English sentence structure and communicative expression.

LITERATURE REVIEW

The study of function words has long held an important place in English linguistics, although the degree of attention given to these units has changed from one theoretical tradition to another. In traditional grammar, function words are usually described as grammatical elements that help organize sentence structure rather than carry full lexical meaning. At first sight, this may make them seem less important than nouns, main verbs, adjectives, or adverbs. However, many linguistic studies show that this impression is incomplete. In actual English usage, function words are deeply involved in sentence formation, clause connection, and meaning construction, which makes them far more significant than a simple “supporting” label might suggest.

One of the most influential foundations for the study of English function words can be found in the work of Quirk, Greenbaum, Leech, and Svartvik. In their comprehensive description of English grammar, these scholars treat grammatical words as an essential part of the structural system of the language. Their work shows that such units are necessary for clause building, grammatical relations, and syntactic linkage. A similar view is presented by Greenbaum and Quirk, who describe function words as part of the closed grammatical system of English and explain that they are not optional additions, but fixed and necessary components of acceptable sentence patterns. These works remain highly useful because they clearly demonstrate that grammatical meaning in English is often distributed through relatively small but structurally indispensable words.

A more detailed modern account appears in Huddleston and Pullum, who analyze auxiliaries, prepositions, determiners, and conjunctions as integral parts of clause architecture. Their approach is particularly valuable because it moves beyond simplified school-style grammar and offers a more realistic explanation of how grammatical categories function in actual syntax. Carter and McCarthy, drawing on spoken and written corpus evidence, also show that grammar cannot be fully understood through isolated rule statements alone. Their work makes it clear that grammatical words need

to be observed in authentic language use, not only in artificially constructed examples. This point is especially relevant for the present study, since one of its main assumptions is that function words should be examined not only as formal units, but also as part of real communicative practice.

Functional linguistics offers another important perspective on the issue. Halliday and Matthiessen argue that grammar should be understood through the meanings it helps construct in discourse. From this viewpoint, function words are not empty structural fillers. They actively participate in the organization of experiential, interpersonal, and textual meaning. Auxiliary verbs help express tense, aspect, polarity, and clause type; modal verbs convey speaker stance, degree of certainty, and interpersonal attitude; prepositions define relations between events, participants, and circumstances; conjunctions organize logical and textual relations between clauses and larger stretches of discourse. Thompson supports this position by showing that grammar in real communication is inseparable from the communicative purposes it serves. This functional view is especially important for the present article because it helps explain why function words should be studied not only structurally, but also communicatively.

Corpus linguistics has made a particularly strong contribution to the study of function words. Sinclair notes that repeated patterns in authentic language use often reveal grammatical behavior more clearly than invented examples. This observation is highly relevant because function words are among the most frequent and structurally recurrent elements in English. Corpus-based studies show that such words appear in stable phraseological and grammatical patterns that learners need repeated exposure to in order to internalize them. Biber, Johansson, Leech, Conrad, and Finegan also demonstrate that grammatical words occur with high frequency across both spoken and written English, even though their exact distribution may vary from one register to another. These findings support the view that function words are not marginal details of grammar; they belong to the most regularly used resources in the language.

From a pedagogical point of view, the issue becomes even more practical. Swan notes that many learner problems in English arise not from vocabulary itself, but from the correct use of grammatical words and constructions. This observation is particularly relevant in contexts where the learner’s first language is structurally different from English. In Uzbek-speaking classrooms, many difficulties with auxiliary verbs, modal distinctions, prepositions, and clause connectors can be explained through typological contrast. Learners often understand the lexical meaning of a sentence, but still struggle with the smaller grammatical units that make the sentence sound correct and natural in English. This shows that function words are not only a theoretical issue in grammar; they are also a major practical issue in language teaching and learner performance.

Despite the significant amount of previous research, an important gap still remains. Many studies describe function words either as formal grammatical categories or as isolated learner difficulties, but fewer

works consider them as a unified structural and communicative system within English sentence organization. There is still a need for a more integrated explanation of how auxiliary verbs, modal verbs, prepositions, and conjunctions work together in authentic English, and how this knowledge can be applied in contrastive teaching contexts such as English and Uzbek. The present article attempts to respond to this need by combining grammatical description, corpus-based observation, contrastive analysis, and pedagogical interpretation within a single analytical framework.

CORPUS BASIS AND RESEARCH METHODS

The empirical basis of this study consists of authentic English-language material taken from two widely recognized corpora: the British National Corpus (BNC) and the Corpus of Contemporary American English (COCA). These corpora were selected because they provide a broad and reliable representation of naturally occurring English across different communicative domains, including spoken interaction, academic writing, journalistic texts, fiction, and everyday usage. Since the purpose of the research is to investigate how function words operate in real sentence structure rather than only in textbook examples, corpus material offers a more convincing and practical foundation for analysis.

For the purposes of the study, 2,500 English sentences were selected from the corpus data. The sample was limited to sentences containing the four function-word categories chosen for closer examination: auxiliary verbs, modal verbs, prepositions, and conjunctions. These categories were selected because they are highly frequent in English and because they play a direct role in grammatical organization, clause connection, and communicative interpretation. The collected material included both relatively simple and more structurally developed sentence types in order to reflect a broader range of authentic usage. Care was also taken not to limit the sample to only one register or one narrow discourse type, since function words perform differently across contexts.

Several complementary methods were used in the research so that the selected material could be examined from both linguistic and pedagogical perspectives. The first was the descriptive method, which made it possible to identify, classify, and group the selected function-word categories within the corpus sample. This stage was necessary in order to observe where these units occur in sentence structure and what kinds of grammatical patterns they help create. The second was the functional-semantic method, which was used to interpret how these forms contribute to meaning in context. This was especially important because function words often perform more than one function depending on the syntactic environment and the communicative purpose of the utterance.

The study also applies a contrastive method, since one of its practical aims is to explain why Uzbek learners of English often experience difficulty in the use of function words. Through comparison, it becomes easier to see that English frequently expresses grammatical meanings through separate function words, whereas

Uzbek often relies more heavily on suffixes or other structural devices. These differences help explain recurrent learner errors, especially in the use of auxiliary verbs, modal constructions, prepositions, and conjunctions.

In addition, the statistical method was employed in order to observe the relative frequency and distribution of the selected categories within the corpus sample. Although the overall orientation of the study is mainly qualitative, quantitative support increases the reliability of the analysis and helps demonstrate that the selected function words are not occasional or peripheral features of English. On the contrary, their high frequency confirms that they belong to the regular grammatical framework through which English sentences are built and interpreted.

It should also be noted that the scope of the study is intentionally limited to four categories of function words. Other grammatical classes such as articles, determiners, pronouns, and particles were not included in the main empirical discussion, not because they are unimportant, but because the study required a manageable and focused analytical range. The research procedure therefore moved through several stages: first, relevant examples were identified and grouped according to the selected categories; second, the examples were classified according to their grammatical function; third, their semantic and communicative contribution was examined in context; and finally, English structures were compared with approximate Uzbek equivalents in order to highlight typological differences and pedagogical implications.

Such a methodological design makes it possible to approach function words not merely as formal grammatical items, but as active components of sentence organization and communicative meaning. By combining corpus evidence with structural description, contextual interpretation, contrastive observation, and frequency-based support, the study aims to provide a more balanced and practically useful account of how these units function in authentic English.

ANALYSIS OF FUNCTION WORDS IN ENGLISH SENTENCE STRUCTURE

The analysis of the selected corpus material clearly shows that function words occupy a highly visible and structurally important place in authentic English sentence formation. In the sample of 2,500 sentences taken from the British National Corpus (BNC) and the Corpus of Contemporary American English (COCA), the four categories selected for this study—auxiliary verbs, modal verbs, prepositions, and conjunctions—appeared with considerable regularity across different types of discourse. This repeated occurrence supports the main argument of the article: function words should not be treated as minor grammatical accessories, but as central elements that help shape sentence organization, grammatical completeness, and communicative clarity.

One of the most noticeable findings of the corpus analysis is the overall frequency of the selected categories. Among the four groups, prepositions occurred most often, which is not surprising considering the analytic nature of English and the wide range of semantic

relations that prepositional structures express. They were followed by conjunctions, which play a major role in clause connection and textual flow. Auxiliary verbs and modal verbs also appeared frequently, which confirms their importance in verbal structure, clause type, and speaker meaning. This distributional pattern shows

that function words are deeply embedded in the grammatical system of English and appear not as occasional forms, but as highly recurrent structural resources.

Frequency and Distribution of Major Function-Word Categories

Table 1.

Frequency of Major Function-Word Categories in the Corpus

| Function-Word Category | Number of Occurrences (in 2,500 Sentences) | Percentage |
|------------------------|--|------------|
| Auxiliary verbs | 1,857 | 74.3% |
| Modal verbs | 1,634 | 65.4% |
| Prepositions | 2,187 | 87.5% |
| Conjunctions | 1,923 | 76.9% |

Source: Compiled by the author on the basis of BNC and COCA corpus samples.

The figures in Table 1 show that prepositions were the most frequent category in the analyzed sample, appearing in 87.5% of the sentences. This high frequency reflects the fact that English relies heavily on prepositional constructions to express spatial, temporal, directional, causal, and abstract relations. Conjunctions also appeared in a large proportion of the corpus material, which highlights the importance of explicit clause linking and logical sequencing in English discourse. Auxiliary verbs were found in 74.3% of the sentences, while modal verbs occurred in 65.4%. Although modal verbs were the least frequent of the four selected categories, their presence remained substantial and confirms their important role in expressing speaker attitude, modality, and interpersonal meaning.

Auxiliary Verbs and Modal Verbs in Sentence Formation

The corpus analysis shows that auxiliary verbs are among the most structurally important elements in English sentence formation. In the selected material, auxiliary verbs most frequently appeared in progressive and perfect constructions, passive voice patterns, negative clauses, and interrogative forms. The verbs *be*, *have*, and *do* repeatedly functioned as grammatical operators rather than as lexical carriers of independent meaning. Their role was especially clear in sentences where tense, aspect, polarity, or clause type depended entirely on their presence. Without these elements, many of the examined sentences would have become incomplete, ungrammatical, or semantically distorted.

At the same time, the analysis suggests that auxiliary verbs should not be seen only as formal markers. They also influence how an event is presented and understood in discourse. For example, the difference between *He writes*, *He is writing*, and *He has written* is not simply a matter of grammar form. Each construction presents the same event from a different temporal or aspectual perspective, which changes how the message is interpreted. This observation supports the idea that auxiliary verbs participate directly in the shaping of meaning, not only in the formation of acceptable grammatical patterns.

Modal verbs reveal a somewhat different but equally important pattern. In the corpus material, forms such as *can*, *could*, *may*, *might*, *must*, *should*, *will*, and *would* were regularly used to express possibility, necessity, obligation, advice, prediction, and varying degrees

of certainty. Unlike auxiliary verbs, which mainly organize grammatical structure, modal verbs are especially important in the interpersonal dimension of language. They allow speakers and writers to position themselves in relation to the message and to signal attitude, confidence, politeness, or evaluation. In many cases, the presence of a modal verb changes not only the literal meaning of the sentence, but also its tone and pragmatic force. This makes modal verbs especially significant in both grammatical analysis and language teaching.

Prepositions and Conjunctions as Structural and Cohesive Devices

Among all the selected categories, prepositions showed the highest frequency in the corpus, which clearly confirms their central role in English. They were found in a wide range of functions, including the expression of place, time, direction, cause, purpose, means, and more abstract relational meanings. Examples such as *in the classroom*, *on Monday*, *by train*, *for learning*, and *with confidence* illustrate how prepositions help define the relationship between actions, participants, and circumstances. Their high frequency also confirms that English depends strongly on separate grammatical markers to express relational meaning.

The analysis further shows that prepositions are highly sensitive to context and usage. In many cases, the choice of preposition cannot be predicted by simple logic alone. Small changes in prepositional selection may alter the meaning of the phrase or make the sentence sound unnatural. This is one of the main reasons why prepositions are often difficult for learners. Their use is closely tied to conventional patterns, collocational behavior, and exposure to authentic language rather than to rule memorization alone.

Conjunctions also played a major role in the analyzed material. They were used to connect words, phrases, and clauses, and to make logical relations between ideas more explicit. Coordinating conjunctions such as *and*, *but*, and *or* linked units of equal status, while subordinating conjunctions such as *because*, *although*, *if*, *when*, and *while* introduced dependent clauses and expressed more specific semantic relations. These forms helped signal addition, contrast, reason, condition, sequence, and result. From a discourse perspective, conjunctions are especially important because they guide readers and listeners through the internal logic of the text. In this sense, they function not only as

syntactic connectors, but also as devices of cohesion and interpretation.

Typical Difficulties for Uzbek Learners of English

One of the most practically important findings of the study concerns the difficulties that Uzbek learners of English often face when using function words. The contrastive analysis suggests that many of these problems are closely connected with typological differences between English and Uzbek. Since English is largely analytic and Uzbek is agglutinative, similar meanings are often expressed through very different grammatical mechanisms. As a result, learners may unconsciously transfer native-language patterns into English and produce errors that affect grammaticality, clarity, or naturalness.

Auxiliary verbs are a frequent source of difficulty. Because Uzbek does not use equivalent auxiliary structures in the same way as English, learners may omit auxiliaries in progressive forms, negative sentences, or interrogative patterns. Errors such as *She going to school* or *You like tea?* clearly show how omission or incorrect formation can disturb the grammatical struc-

ture of the sentence. These patterns suggest that learners often understand the main lexical meaning, but fail to supply the structural element required in English.

Modal verbs create a somewhat different challenge. Learners may confuse forms that seem close in meaning but differ in force, politeness, or context. For example, *can* may be overused in situations where *should*, *may*, or *must* would be more appropriate. This is particularly important in formal, academic, or socially sensitive communication, where modal choice can affect not only meaning, but also tone.

Prepositions are perhaps the most difficult category in practical classroom experience. Since Uzbek often expresses similar relations through suffixes or alternative grammatical structures, learners may not always find a direct one-to-one equivalent for English prepositions. This can lead to incorrect choice, omission, or overgeneralization. Conjunctions may also be used awkwardly when clause-linking patterns from Uzbek are transferred directly into English. Such cases show that function-word errors are not random; they often reflect deeper structural differences between the two languages.

Table 2.

Common Difficulties Observed in Uzbek Learners' Use of Function Words

| Category | Typical Difficulty | Example of Incorrect Use | Correct Form |
|-----------------|-------------------------------|---|---|
| Auxiliary verbs | Omission in progressive forms | <i>She going to school</i> | <i>She is going to school</i> |
| Auxiliary verbs | Incorrect question formation | <i>You like tea?</i> | <i>Do you like tea?</i> |
| Modal verbs | Confusion of modal meaning | <i>You can submit it tomorrow</i> | <i>You should / must submit it tomorrow</i> |
| Prepositions | Wrong preposition choice | <i>Interested on English</i> | <i>Interested in English</i> |
| Conjunctions | Unnatural clause linking | <i>Because he was tired but he worked</i> | <i>Although he was tired, he worked</i> |

The examples in Table 2 show that many learner errors are directly linked to structural transfer and incomplete awareness of how function words operate in English. For this reason, the teaching of these forms should move beyond isolated grammar rules. Better results are more likely when learners meet function words in context, work with authentic examples, compare English structures with Uzbek equivalents, and practice them in meaningful communicative tasks.

Pedagogical Significance of the Findings

From a pedagogical point of view, the findings of the study suggest that function words deserve much more focused attention in English language teaching than they often receive. In many classrooms, learners spend more time memorizing lexical vocabulary, while grammatical words are treated as small technical details. However, the corpus evidence and contrastive observations presented in this study show that errors in function-word usage often have a greater effect on grammatical accuracy and communicative naturalness than lexical gaps alone.

This means that function words should be taught as part of a broader communicative grammar approach. Corpus-based examples can help learners see how these forms appear in authentic English. Contextualized

grammar practice can show how they behave in real sentences rather than only in isolated exercises. Contrastive English-Uzbek explanation can reduce negative transfer by making structural differences more visible. When function words are taught in this way, learners are more likely to understand not only where these forms appear, but also why they matter for meaning, clarity, and coherence.

Taken together, the analysis confirms that function words are central to both the structural and communicative dimensions of English. Their frequency, flexibility, and functional range make them indispensable in authentic language use. For this reason, they should be treated as an important area of both linguistic research and practical pedagogy.

CONCLUSION

The present study has shown that function words occupy a central place in English sentence structure and should be understood as both structural and communicative elements of the language. Although these units are often described as secondary grammatical items because they usually carry limited independent lexical meaning, the analysis makes it clear that their role is much broader than simple grammatical support. Auxiliary verbs, modal verbs, prepositions, and conjunctions

contribute directly to sentence formation, clause connection, semantic interpretation, and discourse cohesion. In this sense, they are not peripheral features of English grammar, but part of the core system through which meaning is organized and expressed.

The corpus-based analysis of 2,500 sentences drawn from the British National Corpus (BNC) and the Corpus of Contemporary American English (COCA) confirms that the selected categories of function words appear with high frequency in authentic English. Their repeated presence across different types of discourse shows that they function as stable and indispensable components of sentence construction. The especially high frequency of prepositions and conjunctions highlights the extent to which English relies on explicit grammatical markers to express relational and logical meanings. The findings also show that auxiliary and modal verbs play an important role not only in grammatical structure, but also in the way actions, events, attitudes, and speaker intentions are presented.

An equally important outcome of the study is its pedagogical relevance. The contrastive observations suggest that Uzbek learners of English often face recurring difficulties in the use of function words because English and Uzbek rely on different grammatical strategies. Since English commonly uses separate grammatical words to express meanings that Uzbek may encode through suffixes or alternative structures, learners may omit auxiliaries, misuse modal forms, choose unsuitable prepositions, or connect clauses in ways that sound less natural in English. These difficulties are not isolated mistakes; they reflect deeper typological differences that should be taken seriously in classroom practice.

From a teaching perspective, the study supports a more integrated and context-sensitive approach to grammar instruction. Function words should not be presented only through isolated rules or mechanical drills. More effective learning can be achieved when these forms are taught through authentic examples, corpus-based observation, contextualized usage, and contrastive English-Uzbek explanation. Such an approach helps learners understand not only the formal position of function words in sentence structure, but also their practical role in creating clarity, coherence, and communicative effectiveness.

In summary, the article shows that function words deserve more focused consideration in both linguistic description and English language pedagogy. Their contribution extends beyond formal grammatical correctness and directly affects how ideas are connected, how meanings are specified, and how messages are understood in real communication. For this reason, the study of function words remains an important area for further research, especially in relation to learner corpora, classroom methodology, and the analysis of other grammatical categories such as articles, determiners, pronouns, and particles.

References

1. Biber, D., Johansson, S., Leech, G., Conrad, S., & Finegan, E. (1999). *Longman grammar of spoken and written English*. London: Longman.
2. Carter, R., & McCarthy, M. (2006). *Cambridge grammar of English: A comprehensive guide*. Cambridge: Cambridge University Press.
3. Greenbaum, S., & Quirk, R. (1990). *A student's grammar of the English language*. London: Longman.
4. Halliday, M. A. K., & Matthiessen, C. M. I. M. (2014). *Halliday's introduction to functional grammar* (4th ed.). London: Routledge.
5. Huddleston, R., & Pullum, G. K. (2002). *The Cambridge grammar of the English language*. Cambridge: Cambridge University Press.
6. Leech, G. (2004). *Meaning and the English verb* (3rd ed.). London: Routledge.
7. Quirk, R., Greenbaum, S., Leech, G., & Svartvik, J. (1985). *A comprehensive grammar of the English language*. London: Longman.
8. Sinclair, J. (1991). *Corpus, concordance, collocation*. Oxford: Oxford University Press.
9. Swan, M. (2016). *Practical English usage* (4th ed.). Oxford: Oxford University Press.
10. Thompson, G. (2014). *Introducing functional grammar* (3rd ed.). London: Routledge.
11. British National Corpus (BNC). (n.d.). *British National Corpus*.
12. Corpus of Contemporary American English (COCA). (n.d.). *Corpus of Contemporary American English*.

Viorica Cazac,*PhD, Nicolae Testemitanu SUMPh, Republic of Moldova
viorica.cazac@usmf.md***Liuba Maxian,***lecturer, Nicolae Testemitanu SUMPh, Republic of Moldova
liuba.chiviriga@usmf.md*<https://doi.org/10.5281/zenodo.19556838>

ARTIFICIAL INTELLIGENCE IN EMP: AN EMPIRICAL STUDY OF STUDENT PERCEPTIONS AT NICOLAE TESTEMITANU SUMPH

Abstract

The fulminant advance of artificial intelligence (AI) into higher education is fundamentally altering how medical students acquire and process clinical knowledge, particularly in how students search for information, organize learning materials, generate ideas, and complete academic tasks. This exploratory study investigates the perceptions and usage habits of 65 students at the Nicolae Testemitanu State University of Medicine and Pharmacy regarding AI tools within EMP (English for Medical Purposes) classrooms. The study involved a cross-sectional survey design across five medical faculties, whereas the findings revealed a high rate of AI usage among medical students who use large language models (LLMs) like ChatGPT on a daily or weekly basis. In the context of EMP, students opt for AI-tools mainly for searching for information, summarizing texts, and translating complex medical terminology, etc. This article discusses the implications of these empirical findings for medical English education, highlighting both the advantages of AI in saving time and clarifying content, as well as the need for structured institutional guidelines.

Keywords: *artificial intelligence, medical education, EMP, ChatGPT, medical students*

1. Introduction

The increasing advance of artificial intelligence (AI) into social, economic, and personal life, especially in university settings, represents an important paradigm shift, opening new opportunities to improve teaching practices and student engagement. This technological evolution is particularly critical in the context of globalized medical education, where English proficiency serves as the dominant lingua franca for international research, clinical collaboration, and professional worldwide communication. This issue is particularly relevant for non-native English students from different medicine-related specialties, who also require extensive theoretical background, specialized terminology, and demanding academic workloads. In such contexts, AI tools may support learning by facilitating information search, summarizing difficult material, explaining concepts more clearly, and assisting with written assignments. At the same time, the growing accessibility of these tools raises important pedagogical issues regarding their educational value, their practical usefulness, and their possible role in the development of academic skills [1, 7].

The Nicolae Testemitanu State University of Medicine and Pharmacy (USMF), established in 1945, is the premier medical higher education institution in the Republic of Moldova. Operating as a highly internationalized academic hub, SUMPh hosts a diverse student body of over 6,000 individuals originating from more than 50 countries. To accommodate this demographic diversity, the university provides a variety of training programs in four languages: Romanian, English, French, and Russian. However, for international students, as well as local students aiming for global mobility, Medical English acquisition is both an academic precondition and a clinical requirement [2, 3].

Despite the widespread use of AI tools in language learning, there remains a critical gap in empirical data regarding how medical students actually use these tools in real-world or career-oriented settings. Therefore, this exploratory study aims to investigate the perceptions, usage frequencies, and platform preferences of SUMPh students across various medical faculties. By analyzing the survey data, we tried to understand how generative AI supports the educational experience of future healthcare professionals [4, 5].

2. Methods

This study was designed as a short descriptive, cross-sectional, exploratory survey aimed at obtaining preliminary data on students' perceptions and uses of artificial intelligence in academic learning. It was conceived as an initial stage of a broader prospective investigation into the role of AI in university education, with particular relevance for English language learning in a medical academic context.

The survey was conducted among 65 students from several faculties of Nicolae Testemitanu State University of Medicine and Pharmacy, including Medicine, Dentistry, Radiology, Pharmacy, and Nursing. Data were collected through Google Forms using a brief questionnaire consisting of five multiple-choice questions focused on AI use in study-related contexts.

Data was collected utilizing a structured, five-question digital survey administered via Google Forms. The questionnaire was deliberately concise to maximize response rates among medical students with demanding schedules. The survey evaluated 5 core components, including: (1) which AI platforms students use most often; (2) how often they use AI tools for study-related purposes; (3) what they mainly use AI tools for; (4) which AI platform they consider the most useful for

their studies; and (5) what they regard as the main advantage of using AI in education.

The questionnaire was intentionally brief and explanatory in nature. Its purpose was not to provide an exhaustive evaluation of AI use, but rather to identify general tendencies in student behavior and attitudes.

3. Results

The empirical data collected from the 65 respondents provides an overall picture of how AI tools are currently implemented into the academic experiences of

SUMPh students. The results are categorized according to the dimensions evaluated in the survey.

3.1 Frequency of AI Tool Usage

The survey results indicate a considerable high rate of AI usage among the student cohort. As illustrated in Figure 1, AI tools have shifted from occasional assistance to daily routines.

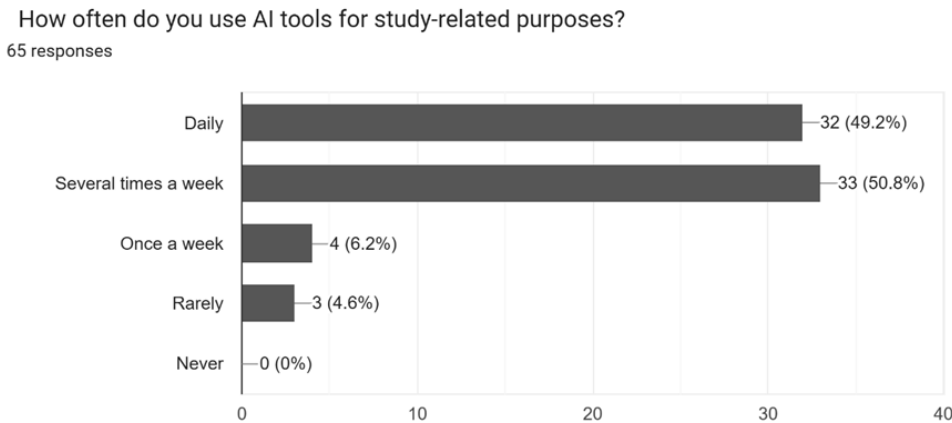


Figure 1: How often do you use AI tools for study-related purposes?

The data shows that 49.2% (n=32) of the surveyed students use AI tools on a "daily" basis. Furthermore, 50.8% (n=33) reported using these tools "several times a week." (Note: Due to the multiple-choice configuration of this specific survey parameter, overlapping response may occur). Just a few students 6.2% (n=4) mentioned using AI "once a week," 4.6% (n=3) using it

"rarely," and 0% reporting "never" using AI tools. This almost confirms the total integration of AI technology into the students' study practice.

3.2 Dominant AI Platforms

Although many AI tools are available, students tend to prefer mainstream conversational LLMs.

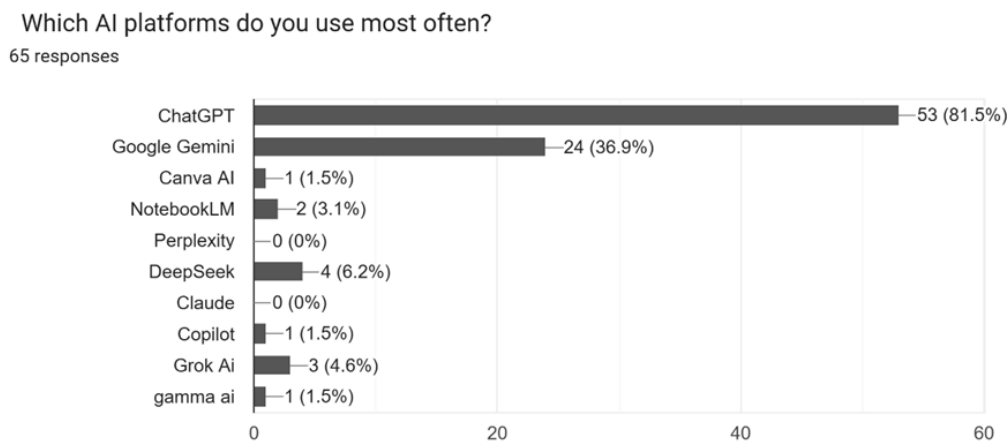


Figure 2: Which AI platforms do you use most often?

When asked which platforms students use most frequently, Figure 2 reveals a significant predominance of OpenAI's ChatGPT, which was selected by an overwhelming 81.5% (n=53) of respondents. Google Gemini emerged as the second most popular platform, in 36.9% (n=24) of the students. Other platforms had a significantly lower rate of use: DeepSeek (6.2%, n=4), Grok AI (4.6%, n=3), NotebookLM (3.1%, n=2),

Canva AI (1.5%, n=1), Copilot (1.5%, n=1), and gamma ai (1.5%, n=1). Notably, tools like Claude and Perplexity (which are valuable academic tools for research and source discovery) received 0% in this category.

3.3 Primary Applications in Medical and Linguistic Studies

To understand how AI functions in students' learning, participants were asked to identify their main

uses of these tools, revealing how AI supports both cognitive and linguistic tasks.

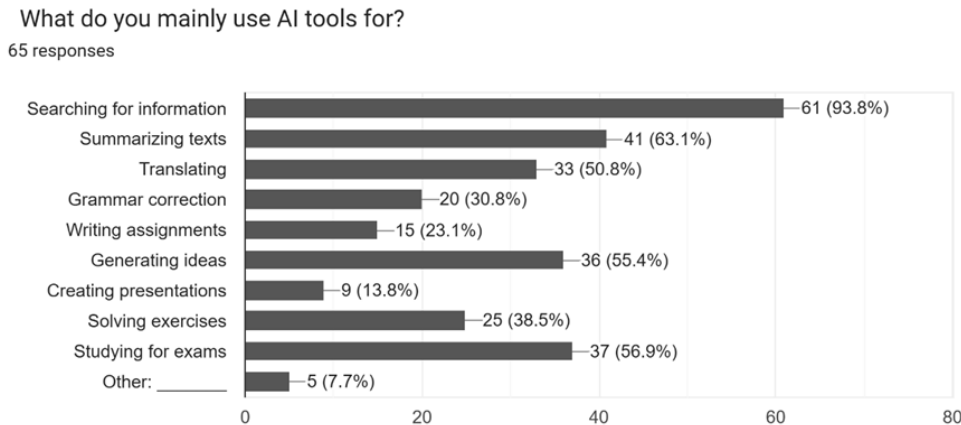


Figure 3: What do you mainly use AI tools for?

As shown in Figure 3, the most common response is "searching for information," selected by 93.8% (n=61) of the cohort. However, linguistic and text-processing applications are also highly significant. "Summarizing texts" is used by 63.1% (n=41) of students, indicating that AI serves as an important tool for processing complex medical literature. Directly related to English language acquisition, 50.8% (n=33) use AI for "translating," and 30.8% (n=20) rely on it for "grammar

correction." Other notable academic uses include "studying for exams" (56.9%, n=37), "generating ideas" (55.4%, n=36), "solving exercises" (38.5%, n=25), and "writing assignments" (23.1%, n=15).

3.4 Main Advantages of AI in Education

Finally, the survey investigated the perceived educational benefits of AI, showing how students assess its value in the learning process

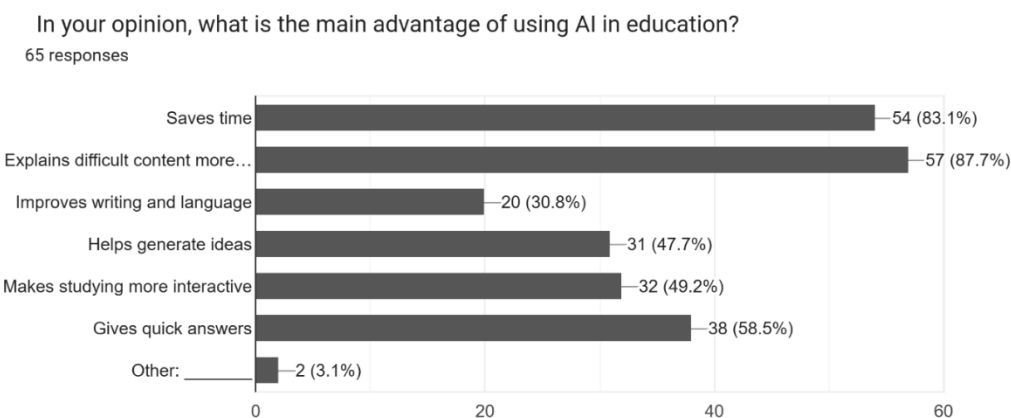


Figure 4: In your opinion, what is the main advantage of using AI in education?

According to Figure 4, the primary advantage perceived by SUMP students is explaining difficult content more clearly, with 87.7% (n=57). This was followed by saving time, with 83.1% (n=54) and 58.5% (n=38) valuing that it "gives quick answers." Importantly for international students navigating an English-heavy curriculum, 30.8% (n=20) explicitly identified that AI "improves writing and language." Nearly half of the students also reported that AI "makes studying more interactive" (49.2%, n=32) and "helps generate ideas" (47.7%, n=31). Overall, these findings suggest that students value AI primarily for efficiency, clarity, and immediacy rather than exclusively for language-related support.

4. Discussion

The findings of this preliminary survey show that AI tools have already become part of students' academic routines at Nicolae Testemițanu State University of Medicine and Pharmacy. The results suggest that students do not perceive AI primarily as a novelty, but rather as a practical study aid that supports everyday academic tasks. The fact that zero students reported "never" using AI, and over 90% exploit it multiple times a week or daily (Figure 1), corresponds to the emerging global literature on the widespread integration of generative AI into medical education [6].

A particularly important finding is that students use AI above all for searching for information, summarizing texts, studying for exams, generating ideas, and translating. This pattern shows that AI is mainly associated with cognitive support and academic efficiency. In other words, students seem to use these tools not only to obtain answers, but also to process large volumes of information in a faster way. This is especially understandable in a medical university context, where students work with extensive theoretical material and difficult concepts. Therefore, the data in Figure 3 reveals that over 63% of students use AI for summarizing texts, and over 50% use it for translation. In this context, LLMs such as ChatGPT, selected by 81.5% of respondents as the platform they use most often (Figure 2), appear to function as effective tools for selecting, simplifying, and organizing information [1].

However, the heavy reliance on AI for searching for information (93.8%) and explaining difficult content (87.7%) raises important pedagogical concerns. While LLMs are often quite convincing, they are probabilistic language models rather than validated medical knowledge systems. Their use as primary sources of medical information therefore may lead to the risk of clinically inaccurate content. This risk may be particularly significant for non-native English-speaking students who rely on AI to translate or explain complex information. Subsequently this might further result in misunderstanding, serious academic or even clinical consequences [6].

This point is equally relevant for English language teaching. Even though the survey did not examine English learning directly as a separate category, several of the reported uses of AI are clearly connected with language-related tasks. Translation, grammar correction, summarizing, idea generation, and writing support are all functions that can be productively integrated into English for Medical Purposes classes. Thus, the data do not show that students use AI mainly for communication in English; rather, they suggest that students approach AI primarily as a study tool, while its language-learning potential remains secondary. This is an important pedagogical observation. It means that the educational value of AI for English may depend not only on student initiative, but also on the teacher's ability to structure and direct its use [2, 3, 4, 5].

From this perspective, the role of the teacher becomes essential. If students already use AI spontaneously for academic purposes, English teachers in medical universities should transform it into guided teaching-learning process. For example, AI can be used for vocabulary expansion, grammar awareness, paraphrasing medical texts, generating discussion prompts, practicing written responses, or creating a variety of AI-assisted authentic materials [2, 3].

At the same time, the present findings should be interpreted with caution. This was a short exploratory survey involving a relatively small sample of 65 students from several faculties, and the questionnaire consisted of only 4 multiple-choice items. Its purpose was to identify general tendencies rather than provide deep explanatory analysis. In addition, the study explored AI use for academic purposes in general, not exclusively for English language learning. For this reason, any conclusions about English must remain preliminary. A

broader study is required, including a larger student sample, more detailed questions, and qualitative components such as open-ended responses or interviews in order to examine how students perceive the role of AI in learning English.

Overall, the findings support the idea that AI should not be ignored in English teaching, but rather explored as a pedagogical resource within a structured and academically guided framework.

5. Conclusion

This empirical study demonstrates that students across various faculties at USMF Nicolae Testemițanu have rapidly and comprehensively adopted artificial intelligence into their academic workflows. Driven by the need to save time, decode difficult content, and navigate the linguistic complexities of Medical English, students rely heavily on conversational platforms like ChatGPT and Google Gemini for translation, text summarization, and grammar correction. While these tools offer profound benefits for personalized English language acquisition and cognitive offloading, their ubiquitous use necessitates formal guidance. Future longitudinal research is required to evaluate the long-term impact of AI on clinical competence and to establish robust institutional frameworks that teach students how to critically and ethically interact with AI-generated medical content.

References

1. Abd-Alrazaq A, AlSaad R, Alhuwail D, Ahmed A, Healy PM, Latifi S, Aziz S, Damseh R, Alabed Alrazak S, Sheikh J. Large Language Models in Medical Education: Opportunities, Challenges, and Future Directions. *JMIR Medical Education*. 2023;9:e48291. doi: 10.2196/48291.
2. Cazac V. Effective Use of Authentic Materials within EFL Classes. *Educația din perspectiva conceptului Clasa Viitorului*. 2023;4:24-31. doi: 10.46727/c.cv-2023.p24-31.
3. Cazac V, Armașu-Canțir L. A Review on the Effectiveness of Using Online Authentic Materials within EMP Classes. *Educația din perspectiva conceptului Clasa Viitorului*. 2020;1:262-269.
4. Klimova B, Pikhart M, Al-Obaydi LH. Exploring the Potential of ChatGPT for Foreign Language Education at the University Level. *Frontiers in Psychology*. 2024;15:1269319. doi: 10.3389/fpsyg.2024.1269319.
5. Li J, Zong H, Wu E, Zhang Y, Gao M, Ji C, Zhao Q. Exploring the Potential of Artificial Intelligence to Enhance the Writing of English Academic Papers by Non-Native English-Speaking Medical Students: The Educational Application of ChatGPT. *BMC Medical Education*. 2024;24:736. doi: 10.1186/s12909-024-05738-y.
6. Roustan D, Bastardot F. The Clinicians' Guide to Large Language Models: A General Perspective With a Focus on Hallucinations. *Interactive Journal of Medical Research*. 2025;14:e59823. doi: 10.2196/59823.
7. Sami A, Tanveer F, Sajwani K, Kiran N, Javed MA, Shahbaz A, Malik S, Siddiqi FA, Kamran S, Suleman H, Zia S, Hamid J, Tariq M. Medical students' attitudes toward AI in education: perception, effectiveness, and its credibility. *BMC Medical Education*. 2025;25:82. doi: 10.1186/s12909-025-06704-y.

SOCIAL COMMUNICATIONS

UDC 378

Bussurmanova A.Ch.

Associate Professor of the Department of
Natural Sciences of the Yessenov University
<https://doi.org/10.5281/zenodo.19556854>

IMAGE COMPETENCE OF THE TEACHING STAFF OF YESSENOV UNIVERSITY

Abstract:

This study examines the evolving requirements for university teachers in the context of mass higher education, digital transformation, and the expansion of lifelong learning. Particular attention is given to the concept of image competence as an essential component of professional effectiveness. The paper analyzes the structure of a teacher's professional image and proposes a model describing the key elements of image competence in higher education.

Key words: *image, specifics of the image of a university teacher, pedagogical imageology, image competence.*

In contemporary conditions, higher education is increasingly viewed as a service sector, where students act as consumers who actively choose their educational trajectories. At the same time, the socio-psychological characteristics of students are changing significantly. Research shows that modern students tend to focus on rapid outcomes with minimal effort, demonstrate independence from traditional authorities, and exhibit pragmatic and flexible thinking. However, they are often characterized by a lack of mature decision-making and reduced social engagement. The expansion of access to higher education has also led to a decline in the selectivity of student admission, which has affected overall academic expectations [1].

The rapid development of information technologies and the accessibility of educational resources have fundamentally transformed the role of the teacher. The modern instructor is no longer the sole source of knowledge; instead, their role increasingly involves managing the learning process, organizing information flows, and facilitating communication. This shift requires a high level of digital literacy, communicative competence, and the ability to work effectively with diverse types of information.

The implementation of lifelong learning systems has broadened the age range of learners, making it necessary for teachers to consider age-related differences in cognitive, emotional, and communicative needs. Since teachers cannot select their audience, they must adapt to various student groups, taking into account differences in perception, motivation, and learning styles. This requires flexibility in communication strategies and the ability to create a psychologically comfortable learning environment.

The criteria for evaluating teaching effectiveness are also changing. Greater emphasis is now placed on communication skills, emotional intelligence, and the ability to establish productive interaction with students. The success of the educational process depends largely on how well the teacher understands the characteristics of the audience and how effectively they are perceived by students.

However, many university teachers, despite possessing strong subject knowledge, often lack sufficient pedagogical training and do not fully recognize the importance of managing their professional image. This limits their ability to effectively influence students' learning and development. Addressing this issue requires the development of image competence, which enables teachers to consciously shape and adjust their professional image depending on the context of interaction.

A positive professional image – characterized by openness, friendliness, and credibility – creates a supportive learning environment, fosters trust, and enhances students' motivation. It also contributes to the coordination of interactions within the educational process, forming a unified intellectual and emotional space.

The concept of "image" has been interpreted differently across disciplines, but most definitions emphasize its role as a structured representation that combines both external and internal characteristics and influences perception and behavior. The image performs both cognitive and emotional functions and is shaped by social expectations and cultural stereotypes.

From a pedagogical perspective, image serves as a powerful tool of influence, affecting students' emotional states, attitudes, and behavior. The development of pedagogical imageology as a field of study highlights the importance of image in professional teaching activity and its role in building effective educational relationships.

The professional image of a university teacher is complex, as it combines two distinct dimensions: the image of a researcher and the image of an educator. The researcher image is associated with analytical thinking, scientific productivity, and academic achievements, while the educator image emphasizes communication skills, clarity, accessibility, and emotional engagement. These components are not always equally developed, and institutional support often prioritizes scientific achievements over pedagogical qualities.

Image competence can be defined as the ability and readiness of a teacher to consciously manage their professional image in various pedagogical situations. It includes understanding how an image is formed, perceived, and adjusted, as well as the ability to design and refine it to achieve specific educational goals [2].

The structure of image competence can be described as an integrative system consisting of several components. The cognitive component includes knowledge of image formation mechanisms and communication strategies. The motivational component reflects the teacher's interest in developing their image and mastering relevant techniques. The reflective component involves self-analysis and the ability to evaluate one's image from the perspective of others. The behavioral component encompasses practical skills necessary for effective interaction, such as maintaining attention, creating a positive atmosphere, and ensuring feedback [3-6].

The integration of imageology into teacher training is becoming increasingly important. At Yessenov University, significant experience has been accumulated in studying and applying image competence in

pedagogical practice, which confirms its relevance and effectiveness in improving the quality of education.

References:

1. Lyubimov L.L. The Fading of the Educational Ethos // *Voprosy obrazovaniya*. 2009. No. 1. P. 199–210.
2. Shepel V.M. *Imageology: secrets of personal charm*. M.: Public education, 2002. 576 p.
3. Zmanovskaya E.B. *Guide to Personal Image Management*. SPb: Rech, 2005. 144 p.
4. Petrova E.A. Image and its study in modern science // *News of the Academy of Imageology*. Vol. 1 / edited by EA Petrova. Moscow: RIC AIM, 2005. Pp. 11–14.
5. Kalyuzhny A.A. Social and psychological foundations of the teacher's image: author's abstract. diss. ... doctor of psychological sciences. Yaroslavl, 2007. 38 p.
6. Perelygina E.B. Image as a phenomenon of intersubjective interaction: content and development paths: diss. Dr.ped. Sci. M., 2003. 1008 p.

TECHNICAL SCIENCES

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Bussurmanova A.Ch.Associate Professor of the Department of
Natural Sciences of the Yessenov University
<https://doi.org/10.5281/zenodo.19556875>

RENEWABLE ENERGY SECTOR OF KAZAKHSTAN: ACHIEVEMENTS, CHALLENGES, AND PROSPECTS

Аннотация

Сектор возобновляемых источников энергии Казахстана за последнее десятилетие продемонстрировал значительный рост, обусловленный поддерживающим законодательством, увеличением инвестиционной активности и высоким природным потенциалом страны. В данной работе анализируется текущее состояние развития возобновляемой энергетики в Казахстане с акцентом на рост установленной мощности, структуру энергетических источников и ключевые механизмы государственной политики, способствующие развитию отрасли. По состоянию на 2022 год суммарная установленная мощность возобновляемых источников энергии превысила 2000 МВт, при этом наибольшую долю составляют солнечная и ветровая энергетика. Несмотря на достигнутые результаты, дальнейшее развитие сектора сдерживается рядом существенных факторов, включая устаревшую нормативно-правовую базу, ограниченные балансирующие мощности энергосистемы, зависимость от иностранных инвестиций, тарифные ограничения и недостаточно развитую инфраструктуру для интеграции ВИЭ в энергосистему. Особое внимание уделяется необходимости модернизации законодательной базы, развитию систем накопления энергии и внедрению сбалансированной тарифной политики для обеспечения долгосрочной конкурентоспособности возобновляемой энергетики. В работе также рассматриваются перспективы развития сектора в контексте стратегической цели Казахстана по достижению углеродной нейтральности к 2060 году. Подчеркивается важность разработки отраслевых дорожных карт, укрепления институциональных механизмов и внедрения эффективных инструментов углеродного регулирования, стимулирующих процессы декарбонизации. Полученные результаты показывают, что, несмотря на значительный потенциал, устойчивое развитие возобновляемой энергетики в Казахстане требует комплексных реформ, развития инфраструктуры и повышения инвестиционной привлекательности отрасли.

Abstract

The renewable energy sector of Kazakhstan has experienced significant growth over the past decade, driven by supportive legislation, increasing investment activity, and the country's substantial natural resource potential. This study analyzes the current state of renewable energy development in Kazakhstan, focusing on installed capacity expansion, structural composition of energy sources, and key policy mechanisms that have facilitated sectoral progress. As of 2022, the total installed capacity of renewable energy sources exceeded 2000 MW, with solar and wind energy accounting for the largest shares. Despite these achievements, several critical challenges hinder further development, including outdated regulatory frameworks, limited balancing capacity within the power system, dependence on foreign investment, tariff-related constraints, and insufficient infrastructure for grid integration. Particular attention is given to the need for modernization of the legislative base, expansion of energy storage systems, and implementation of balanced tariff policies to ensure long-term competitiveness of renewable energy. The study also evaluates future prospects of the sector in the context of Kazakhstan's strategic goal to achieve carbon neutrality by 2060. It highlights the importance of developing sector-specific roadmaps, strengthening institutional mechanisms, and introducing effective carbon pricing tools to stimulate decarbonization. The findings suggest that, while Kazakhstan possesses strong potential for renewable energy expansion, achieving sustainable growth will require coordinated policy reforms, infrastructure development, and increased investment attractiveness.

Ключевые слова: возобновляемые источники энергии, Казахстан, энергетическая политика, устойчивое развитие, декарбонизация, энергетический переход.

Keywords: renewable energy, Kazakhstan, energy policy, sustainable development, decarbonization, energy transition.

The total number of renewable energy (RES) facilities in Kazakhstan has increased from 23 to 136 Ministry of Energy of the Republic of Kazakhstan [1]. The installed capacity of RES grew from 94 MW (in 2011) to more than 2065 MW (as of June 2022), which

led to an increase in the share of RES in the electricity generation structure to 3.7% [1,2]. Currently, the total number of operating RES-based power plants is as follows (as of June 2022) [1]:

Table-1

Operating RES Power Plants and Their Capacity

| RES Type | Number of Operating Plants | Installed Capacity, MW |
|--------------------|----------------------------|------------------------|
| Hydropower Plants | 40 | 229.04 |
| Solar Power Plants | 51 | 1093 |
| Wind Power Plants | 40 | 684 |
| Bio Power Plants | 5 | 7.82 |

By the end of 2022, an additional 10 RES-based power plants with a total capacity of 290 MW are planned to be commissioned [1]. By 2025, the total installed capacity of RES is expected to reach at least 3000 MW [3,4].

The key factors behind this growth include:

Legislative support for RES (since 2009 and its further development): establishment of responsible institutions (Financial Settlement Center for RES support), development of market mechanisms (introduction of auctions and investment preferences, guaranteed “green” tariffs, and electricity purchase guarantees) [2,4];

Investments in alternative energy, which have also played a significant role. Currently, the main investors in RES projects (in terms of capacity) are development banks and foreign companies such as Total Open SA, Solarnet, Hevel, and China Power International Holding [3,5].

Despite the achieved results, there are several factors that significantly hinder further dynamic development of the RES sector. The following aspects should be highlighted:

Legislative framework: With the increasing share of RES in the country’s energy balance and the overall development of the sector, the legislative base developed in 2009–2014 has become outdated and requires revision in specific areas. A new, more comprehensive strategy for RES development is needed [2].

Limited balancing capacity: Energy security is a key issue for any energy system. Therefore, it is necessary to create conditions for the development of flexible capacities to stabilize the power system, such as energy storage systems and other flexible sources [6,5].

Investments: As noted, most RES projects in Kazakhstan are financed by foreign investments, mainly in US dollars, which introduces currency risks for investors. Long payback periods and the limited volume of capacity offered in auctions (only 250 MW last year) also discourage many investors [3,7].

Tariff policy: Compared to conventional electricity tariffs, the current higher tariffs for RES make them uncompetitive without state support. A balanced tariff policy is required to ensure competitiveness [8,9].

Underdeveloped infrastructure for RES integration: The aging infrastructure and limited transmission capacity do not allow full integration of existing RES capacity into the power system. Infrastructure development, particularly in remote and isolated areas, with certain state support, could attract potential investors and designate such areas for RES projects [7,10].

The RES sector in Kazakhstan is on the verge of significant transformation, and much depends on the future actions and decisions of the Government. Kazakhstan possesses strong natural potential and a foundational mechanism for RES development, which has

already ensured a 3% share in electricity generation [1,11]. The renewable energy sector must remain dynamic and responsive to new challenges.

The goal of achieving carbon neutrality by 2060 is highly ambitious but inspired by similar targets set by major economies such as the EU and China [11,12]. Achieving this goal requires roadmaps for each sector, as well as strong incentives such as effective carbon pricing and the development of a private carbon market, encouraging economically justified decarbonization decisions [13].

Considering the inevitable decline in demand for fossil fuels, Kazakhstan must analyze and assess how effectively it can create attractive conditions for investors amid growing international competition for new investments in the oil and gas sector [13,14].

References

1. International Energy Agency. *Renewables 2023: Analysis and Forecast to 2028*; IEA: Paris, France, 2023.
2. International Renewable Energy Agency. *Renewable Capacity Statistics 2023*; IRENA: Abu Dhabi, UAE, 2023.
3. World Bank. *Scaling Up Renewable Energy in Kazakhstan*; World Bank: Washington, DC, USA, 2020.
4. Ministry of Energy of the Republic of Kazakhstan. *Development of Renewable Energy Sector in Kazakhstan*; Astana, Kazakhstan, 2022.
5. BP. *Statistical Review of World Energy 2023*; BP: London, UK, 2023.
6. European Commission. *The European Green Deal*; Brussels, Belgium, 2019.
7. United Nations. *Sustainable Development Goals Report 2023*; UN: New York, USA, 2023.
8. Asian Development Bank. *Renewable Energy Development in Central Asia*; ADB: Manila, Philippines, 2022.
9. Kalyuzhnova, Y.; Nygaard, I. Renewable energy policies in Kazakhstan. *Energy Policy* 2018, 123, 330–340.
10. Kerimray, A.; Suleimenov, B.; De Miglio, R. Investigating the energy transition in Kazakhstan. *Energy Strategy Reviews* 2020, 32, 100552.
11. OECD. *Energy Policies Beyond IEA Countries: Kazakhstan 2019*; OECD: Paris, France, 2019.
12. Mukhtarova, K.; Kozhakhmetova, A. Green economy transition in Kazakhstan. *Journal of Environmental Management* 2021, 287, 112–120.
13. UNDP. *Promoting Renewable Energy in Kazakhstan*; UNDP: Almaty, Kazakhstan, 2021.
14. European Bank for Reconstruction and Development. *Kazakhstan Energy Sector Overview*; EBRD: London, UK, 2022.

Bussurmanova A.Ch.

Associate Professor of the Department of
Natural Sciences of the Yessenov University
<https://doi.org/10.5281/zenodo.19556893>

HYDROGEN: TECHNOLOGY AND ITS ROLE IN THE ENERGY SYSTEM

Abstract

Hydrogen is increasingly recognized as a key element in the transition toward sustainable and low-carbon energy systems. This study examines the technological aspects of hydrogen production, its role as an energy carrier, and its integration into modern energy systems. Particular attention is given to different hydrogen production pathways, including gray, blue, and green hydrogen, with emphasis on renewable-based electrolysis as a pathway to achieving zero-emission energy systems. The analysis highlights the strategic importance of hydrogen in sectors where direct electrification is limited, such as aviation, maritime transport, steel production, and the petrochemical industry. In addition, hydrogen is considered a promising solution for energy storage and grid stabilization, especially in systems with a high share of variable renewable energy sources. The multifunctional role of hydrogen in electricity systems, including its use in power generation and as a flexible load through electrolyzers, is also discussed. The study further explores the economic and infrastructural challenges associated with hydrogen deployment, including high production costs, logistics complexity, and the need for large-scale renewable electricity supply. A case study of Kazakhstan demonstrates the country's significant potential for green hydrogen production, supported by large-scale projects in the Mangystau region and international cooperation initiatives. These projects aim to develop industrial-scale hydrogen production and establish Kazakhstan as a key player in the global hydrogen market. The findings indicate that despite existing challenges, hydrogen has strong potential to support decarbonization and energy system transformation. However, its large-scale implementation requires coordinated policy frameworks, technological advancements, infrastructure development, and investment support.

Keywords: *hydrogen energy, green hydrogen, energy systems, decarbonization, renewable energy, Kazakhstan*

Hydrogen is a universal element that is an integral component of almost all organic substances, fossil hydrocarbons, and, most importantly, water [1]. In its molecular form, hydrogen has been an essential raw material for the petrochemical industry and fertilizer production for many decades [2]. In addition to its use as a feedstock, hydrogen and its derivatives are increasingly being considered as energy carriers, becoming one of the key directions in the development of future energy systems [1,3]. In the context of the global climate crisis, hydrogen – especially when produced using renewable electricity – can become one of the main pillars of a successful transition to a zero-emission energy system [3,4].

Although improving energy efficiency and direct electrification are well-known and fundamental tools for reducing greenhouse gas emissions, hydrogen complements the overall system where these measures are insufficient [4]. This is particularly relevant for sectors that currently rely on fossil hydrocarbons, such as aviation, fertilizer production, the petrochemical industry, steel production, and maritime transport [5,6]. Another important aspect is the use of hydrogen to stabilize power grids with a high share of renewable electricity generation [3].

While gray, blue, and turquoise hydrogen are produced based on fossil resources, green hydrogen is generated through water electrolysis powered by renewable electricity [3,7].

Historically, hydrogen has been produced near the point of consumption using fossil resources; however,

hydrogen logistics becomes increasingly important, especially when production sites (particularly for green hydrogen) are located far from consumption centers [7].

Hydrogen has potential applications across various industries. Although it has been used in the chemical industry for several decades, significant growth in its use is now observed in other sectors, such as transport, where hydrogen and its derivatives – such as synthetic hydrocarbon fuels, ammonia, or pure hydrogen – are gaining increasing importance [5,6].

In the electric power sector, hydrogen performs several functions. It can be used to stabilize the electrical system by operating electrolyzers as flexible consumers and by storing and transporting energy in the form of hydrogen [3,8].

Environmentally friendly hydrogen production requires large amounts of renewable electricity. When connected to the grid, such variable loads can help stabilize it. In addition, hydrogen can be used as fuel for power plants, enabling electricity generation during periods of low renewable energy production [8].

Despite all potential use cases in future energy systems, hydrogen remains more expensive than fossil energy sources [2,7]. Moreover, direct use of renewable electricity is generally more efficient and cost-effective whenever possible [3].

Currently, in Kazakhstan, one of the most promising areas of energy development is the implementation of projects aimed at developing climate-neutral hydrogen production and storage technologies [9]. Many of these projects are being carried out in cooperation with

the German-Swedish flagship company Svevind Energy Group [9].

In October 2022, an agreement was signed to build one of the world's largest environmentally friendly hydrogen production facilities in the Mangystau region, with a capacity of 20 GW [9]. The project is being implemented within the framework of an investment agreement between the Government of the Republic of Kazakhstan and representatives of the company "Hy-rasia One," with the participation of President Kassym-Jomart Tokayev and President of the European Council Charles Michel [9].

Wind and solar power plants with a total capacity of 40 GW will be constructed along the Caspian Sea coast. This will supply power to an industrial-scale electrolysis complex capable of producing up to 2 million tons of green hydrogen annually. The project is scheduled to begin in 2030, with full capacity expected by 2032. The estimated cost of the project is approximately \$50 billion [9].

Kazakhstan is interested not only in new technologies but also in the high-quality training of engineering specialists [10]. This aligns with the needs of the modern economy and is supported by strengthening professional and cultural cooperation between universities of different countries [10].

In Aktau, starting from the new academic year, the Kazakhstan-German Engineering Institute will begin admitting students with the aim of training highly qualified specialists. This initiative is being implemented in cooperation with Sh. Yessenov Caspian University of Technology and Engineering (Yessenov University) [10].

Experts in logistics and energy from leading German universities, representatives of government bodies, and international organizations participated in a round table titled "Kazakhstan-German Partnership in Engineering for Sustainable Development of the Mangystau Region" [10].

As a result, opportunities for students to receive high-quality education in both Kazakhstan and Germany have been identified. Students also gain access to

the latest developments and best practices of European scientists, as well as the opportunity to obtain dual degrees recognized internationally [10].

At the Kazakhstan-German Engineering Institute, bachelor's and master's degree programs in "Logistics" and "Energy and Environmental Engineering" will be taught in English and German. By 2030, it is planned to train up to one thousand specialists in the hydrogen industry, enabling the effective implementation of green energy projects in the Mangystau region [10].

References

1. International Energy Agency. *The Future of Hydrogen: Seizing Today's Opportunities*; IEA: Paris, France, 2019.
2. International Renewable Energy Agency. *Hydrogen: A Renewable Energy Perspective*; IRENA: Abu Dhabi, UAE, 2019.
3. International Energy Agency. *Global Hydrogen Review 2023*; IEA: Paris, France, 2023.
4. United Nations. *World Energy Transitions Outlook 2022*; UN: New York, USA, 2022.
5. Staffell, I.; Scamman, D.; Abad, A.V.; et al. The role of hydrogen in decarbonizing energy systems. *Energy Environ. Sci.* 2019, 12, 463–491.
6. Ball, M.; Weeda, M. The hydrogen economy – Vision or reality? *Int. J. Hydrogen Energy* 2015, 40, 7903–7919.
7. International Renewable Energy Agency. *Green Hydrogen Cost Reduction: Scaling up Electrolysers*; IRENA: Abu Dhabi, UAE, 2020.
8. Zeng, K.; Zhang, D. Recent progress in alkaline water electrolysis for hydrogen production. *Prog. Energy Combust. Sci.* 2010, 36, 307–326.
9. Svevind Energy Group. *Green Hydrogen Projects in Kazakhstan*; Svevind: Hamburg, Germany, 2023.
10. Ministry of Energy of the Republic of Kazakhstan. *Hydrogen Energy Development Concept of Kazakhstan*; Astana, Kazakhstan, 2022.

Ботвіновська С. І.,*д. т. н. професор**botvinovska.si@knuba.edu.ua, ORCID: 0000-0002-1832-1342***Щеглов С. П.,***доцент**shcheglov.sp@knuba.edu.ua, ORCID: 0000-0002-9586-4538**Київський національний університет будівництва і архітектури*<https://doi.org/10.5281/zenodo.19556909>

ПРОЄКТУВАННЯ АДАПТИВНОГО ВІБРАЦІЙНОГО КРІСЛА З КРИВОШИПОМ ДЛЯ МАЛОМОБІЛЬНИХ ЛЮДЕЙ

Botvinovska S. I.*professor professor***Shcheglov S.P.***associate*

DESIGN OF AN ADAPTIVE VIBRATION CHAIR WITH A CRANK MECHANISM FOR PEOPLE WITH REDUCED MOBILITY

Анотація

Сидячий спосіб життя став однією з основних причин фізичного занепаду не тільки здорової людини, в більшій мірі це впливає на малорухомих прошарок людей. Тривале сидіння негативно впливає на фізичне здоров'я, травмує м'язи, викликаючи атрофію і застій кровообігу, призводячи до фізичного дискомфорту, навіть до смерті. Тому розробка зручного автоматичного вібраційного крісла для малорухомих груп населення, зменшить цей дискомфорт. В основі механізму крісла пропонується використати ексцентриковий механізм, який буде створювати вібрацію для полегшення фізичних проблем.

Abstract

A sedentary lifestyle has become one of the main causes of physical decline, not only among healthy individuals, but particularly among those who lead a sedentary lifestyle. Prolonged sitting has a negative impact on physical health, injuring muscles, causing atrophy and poor blood circulation, leading to physical discomfort and even death. Therefore, the development of a comfortable automatic vibrating chair for sedentary groups of the population will reduce this discomfort. It is proposed that the chair's mechanism be based on an eccentric mechanism, which will generate vibrations to alleviate physical problems.

Ключові слова: конструювання; адаптивні меблі; ергономіка; вібрація

Key words: design; adaptive furniture; ergonomics; vibration

Постановка проблеми. Основна проблема полягає у відсутності дієвих принципів моделювання та конструювання адаптивних меблів на рівні соціотехнічної системи для маломобільних людей. Наразі існує велика кількість методів проєктування, які вирішують свої задачі тільки в межах свого рівня, зазвичай на рівні мікроергономіки. Це призводить до того, що розробки адаптивних меблів не мають системного підходу у створенні інклюзії для людей з вадами руху, а сконцентровані лише на поліпшенні ергономічних характеристик, залишаючи поза уваги комплексні аспекти інтеграції, комунікації та соціальної взаємодії.

Аналіз останніх досліджень і публікацій. Існує очевидний зв'язок між сидячою поведінкою людини та проблемами зі здоров'ям: дискомфорт у тілі, біль в області шиї, плечей і нижньої частини спини тощо. Крім цього, деякі дослідники виявили проблему зі здоров'ям маломобільних людей, яка полягає в тому, що сидяча поведінка останніх може погіршити вже наявні захворювання людини [5].

Фізична бездіяльність людини залишається четвертим провідним фактором ризику смертності, на який припадає 6% від глобальної смертності [6].

Вібрація всього тіла (WBV) була представлена ще наприкінці 1990-х років. Але дослідження впливу інтенсивності вібрації проводяться до цього часу. Відомо, що людський організм по різному сприймає різні вібрації та її інтенсивність. Інтенсивність вібрації залежить від частоти або кількості коливань за секунду, вимірюється в герцах (Гц). У багатьох дослідженнях було виявлено, що вібраційне крісло з частотою 5 Гц та амплітудою 7,5 мм допомагає поліпшити сон та прибрати втому. Також дослідили, що вплив вібрації всього тіла 4-7 Гц протягом 60 хвилин, яка передається через автомобільне сидіння, допомагає водіям підвищити симпатичну активацію, та уникати сонливості. Крістофер [7] у 2009 році досліджував вплив вібраційного крісла для пацієнтів з хворобою Паркінсона на вібраційну терапію, пацієнти, які щодня проводили 30-хвилинні сеанси в автоматизованому вібраційному кріслі, відчували себе більш комфортно і краще спали після тренувань. Під час WBV суб'єкт

може виконувати вправи, а частоти вібраційних тренажерів працюють в обмеженому діапазоні, зазвичай від 15 до 70 Гц, та амплітудою, зазвичай від 1 до 10 мм [7, 12, 13]. Основна частота вібрації повинна підтримуватися на низькому рівні, а збільшення інтенсивності вібрації можливе лише протягом обмеженого часу. Рекомендований час використання вібраційного пристрою для фізичних вправ становить від 15 до 30 хвилин на сеанс. Результати експериментів показали, що конструкція вібраційного крісла повинна мати регульоване функціональне налаштування вібрації в обмеженому діапазоні [7, 12, 13]. Вібраційні норми покладаються на конструкцію механічного пристрою. Тому дуже важливо для правильної передачі вібрації спроектувати конструкцію де можуть бути застосовані різні типи коливань, такі як: 1. поворотні коливання; 2. бічні коливання (латеральна осциляція); 3. лінійні коливання; 4. складні рухи; 5. електромагнітні коливання. Всі п'ять видів вібраційних типів коливань можуть генерувати певну вібрацію відповідно:

1. Поворотне коливання, в якому верхня платформа коливається навколо фіксованої центральної осі обертання.

2. Латеральна осциляція - пристрій з 4-ма штангами, який призначений для створення коливань вперед-назад.

3. Лінійна вібрація, вона рухається переважно у горизонтальному напрямку, з незначним рухом по вертикалі.

4. Складний рух, що включає ексцентриковий привід, який поєднує в собі плоский 4-балочний пристрій (пристрої) та ексцентрикове колесо для створення складної схеми руху.

5. Електромагнітні коливання - це привід, придатний для створення зворотно-поступального руху для незначного розтягування.

Вібрація необхідна для здоров'я сидячих людей. Тому, автоматичне вібраційне крісло з оптимально визначеними параметрами повинно забезпечити розслаблення м'язів тіла малорухомих людей та полегшити їх фізичний дискомфорт.

Аналіз останніх розробок адаптивних меблів з функцією вібрації. Для маломобільних груп населення адаптивні меблі з функцією вібрації у 2025–2026 роках перейшли з категорії «комфарту» у категорію життєво необхідної асистивної терапії. Основний фокус розробок спрямовано на оптимізацію геометричних параметрів та кінематичних схем, щоб запобігти появі пролежнів та покращити лімфодренаж та сенсорні стимуляції для людини з інвалідністю [1, 2, 3, 4].

Запобігання пролежням та покращення мікроциркуляції за допомогою адаптивної вібрації – демонструє перехід від механічної дії до «розумного» фізіотерапевтичного моніторингу. Розробники зосередилися на вирішенні головної проблеми маломобільних людей: тканинній гіпоксії (кисневого голодування клітин через постійний тиск) [8, 9, 10, 11].

Технологія Active Vibration Therapy (AVT). Лідером у цьому сегменті є компанія *Permobil* у спів-

праці з *VibeTech*. На відміну від звичайного вібромасажу, AVT використовує низькочастотні коливання (20–50 Гц) з малою амплітудою. Така частота резонує з м'язовими волокнами, викликаючи їх мікророзрив без зміни положення тіла. Це працює як «пасивне тренування» судин. Кров не застоюється в капілярах, що на 40-60% знижує ризик виникнення некрозу тканин (пролежнів). Система *Permobil Connect* зчитує час перебування людини в одній позі. Якщо користувач не змінював кут нахилу крісла понад 30 хвилин, вібраційні модулі в сидінні активуються автоматично. Розробники інтегрували вібраційні актуатори безпосередньо в сидіння, в яких вбудовані десятки датчиків тиску. Вібрація вмикається тільки під тими ділянками, де тиск критичний. Такий підхід дозволяє стимулювати кровообіг локально, не турбуючи все тіло користувача, що важливо при підвищеній сенсорній чутливості [14].

Технологія нейром'язової стимуляції. Для людей з параплегією або повною втратою чутливості розробки *Restorative Therapies* пропонують поєднання вібрації з функціональною електростимуляцією. Вібрація в кріслі готує м'язи до електричного імпульсу, знижуючи опір шкіри та покращуючи відгук нервових закінчень. Регулярні сеанси такої адаптивної вібрації допомагають підтримувати м'язовий тонус навіть за відсутності довільних рухів, що полегшує подальшу реабілітацію користувача.

Система Sens8™ 4D, розроблена інженерами компанії *OHCO* (Японія/США), є однією з найбільш технологічних відповідей на виклики атрофії м'язів та підвищеної крихкості тканин у маломобільних людей. Механіка 4D-алгоритму визначає рух роликів у трьох площинах (X, Y, Z) плюс варіативну швидкість. У контексті Sens8™, четвертий вимір – це динамічний темп, що імітує людське доторкання. Система оснащена датчиками зворотного зв'язку, які вимірюють силу опору поверхні. Оскільки кістка чинить більший опір, ніж м'яка тканина, алгоритм миттєво зменшує глибину натискання та інтенсивність вібрації при контакті з жорсткою зоною. Замість різких поштовхів, вібрація подається за принципом синусоїди, що вкрай важливо для людей з низькою м'язовою масою, де нервові закінчення розташовані близько до поверхні шкіри. Крісло має вбудований сканер та створює 3D-модель спини. Воно ідентифікує положення хребців та виступів тазу. Система створює "зони виключення" та програмно обмежує амплітуду вібрації в радіусі 2–3 см навколо ідентифікованих кісткових виступів. Вібрація спрямовується на залишки м'язових волокон вздовж хребта, стимулюючи їх без прямого тиску на самі відростки хребців. Крісло виконує функцію пасивної гімнастики, а саме розширення судин, що дозволяє доставити поживні речовини до атрофованих м'язів, сповільнюючи процес їх подальшої деградації. Для того щоб запобігти механічним пошкодженням капілярів, система використовує «повітряну подушку» яка створює м'який каркас навколо кінцівки або спини, а вібрація працює всередині цього безпечного «кокона» [15].

Технологія *Smooth Ride Suspension (SRS)*, яку активно впроваджують японська компанія *WHILL* та шведська *Permobil*, є фундаментальним проривом у забезпеченні мобільності пацієнта. Для маломобільної людини будь-яка вібрація від нерівної дороги – це не просто дискомфорт, а фактор, що провокує м'язову спастичку, хронічний біль у хребті та швидку втомлюваність.

Ключовою особливістю технології SRS є здатність нейтралізації вібрації. Поглинання низькочастотних коливань відбувається одразу коли візок наїжджає на вибоїну, SRS активує протидію. Колесо піднімається вгору, але сидіння з користувачем залишається на тій самій горизонтальній лінії. Технологія забезпечує «ефект польоту», де коливання від коліс не передаються на раму та хребет. Стабілізація відбувається автоматично, завдяки збільшенню жорсткості зовнішніх амортизаторів. Це дозволяє візку плавно долати перешкоди висотою до 5–7 см (бордюри, пороги) без різкого поштовху, який зазвичай відчуває користувач. Навіть коли сидіння підняте або нахилене, система SRS продовжує стабілізувати положення та не дозволяє втратити рівновагу [16, 17].

Цілі та завдання статті полягають у теоретичному обґрунтуванні та оптимізації соціотехнічного підходу до проектування адаптивних меблів

для маломобільних груп населення. Такий підхід спирається на використання принципів дизайну, що дозволяють розробникам меблів еволюціонувати разом з розвитком асистивних технологій, та дозволяють підтримувати професійну автономію та гідність особам з інвалідністю.

Основна частина. Розробка дизайну крісла велася в декількох аспектах. Дизайн зовнішнього вигляду зроблений на основі біоміметики (*biomimetics*), що є подальшим розвитком біоніки. Натхненням послужили саме природні форми окремих тергтів, склеротизованих частин сегментарних кілець членистоногих. Біоміметика, як міждисциплінарна наукова галузь вивчає природні системи, які мільйони років відточували еволюцію, за для створення нових технологій, матеріалів та інноваційних рішень. Також, структура проектного рішення виробу щодо обрання дизайну крісла доповнена даними з ергономічної антропології (рис. 1), а саме, в основу розробки покладено метод антропометричного аналізу невідповідності, промислового дизайну та машинобудівного проектування, щоб здійснити розумний підбір компонентів та механізмів, а також застосування конструкційних та оздоблювальних матеріалів.

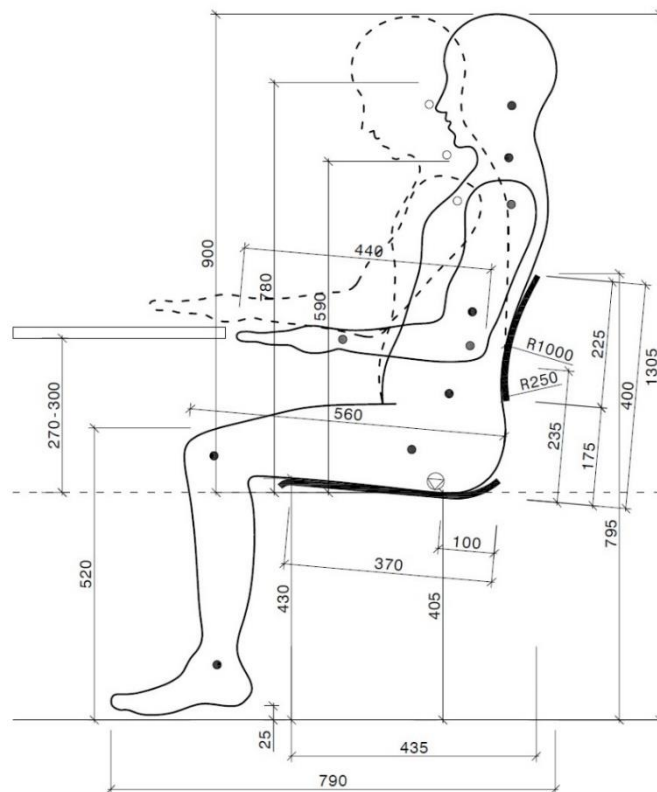


Рис. 1. Ергономічна схема постави людського тіла під час сидіння

Для запобігання м'язово-скелетним розладам при тривалій роботі в сидячому положенні людини, з точки зору антропометрії, конструювання адаптивних меблів базується на аналізі невідповідності (*Mismatch Analysis*). Цей ергономічний аналіз є критичним для забезпечення відповідності пристрою до тіла. Він в основі аналізу лежить використовує

система вигинів тіла для визначення допустимих параметрів меблів:

Висота сидіння (SH):

$$(PH + 2.5) \cos 30^\circ \leq SH \leq (PH + 2.5) \cos 5^\circ \quad (1)$$

де PH - висота підколінної западини. Це забезпечує кут від 5° до 30° у гомілковостопному суглобі, що підтримує кровообіг.

Глибина сидіння (SD):

$$(0.80 \times BPL) \leq SD \leq 0.95 \times BPL \quad (2)$$

де BPL – довжина від сідниці до підколінної западини. Якщо глибина більша за $0.95 BPL$, виникає тиск на судини під колінами; якщо менше $0.80 BPL$ – недостатня підтримка стегон.

Ширина сидіння (SW):

$$1.10 \times HB \leq SW \leq 1.30 \times HB \quad (3)$$

де HB – ширина стегон. Це дає простір для руху та враховує товщину одягу.

Висота ліктів в положенні сидячи (SEH):

$$SEH \leq TH \leq (0.95 + 50) \quad (4)$$

де TH – висота стільниці. Розробка відповідної висоти столу (TH) вимагає ретельного врахування біомеханіки плечей, включаючи кути згинання плечей від 0° до 25° та кути відведення від 0° до 20° ; тримання рук на столі значно зменшує навантаження на хребет.

Висота спинки (BH):

$$(0.60 \times SSH) \leq BH \leq (0.80 \times SSH) \quad (5)$$

Рекомендується, щоб значення BH не було вищим за значення лопатки, тому висота спинки становить від 60% до 80% висоти плечей сидячи (SSH).

Відстань від сидіння до столу

$$(STC): (TT + 20) < STC \quad (6)$$

де TT – товщина стегна. Однак ідеальний розмір STC повинен бути на 20 мм вищим за висоту коліна.

Положення ніг (UTH) з урахуванням (1)-(6):

$$(SH + TT + 30) \leq UTH \leq (SHE + [(PH + 30) \cos 5^\circ] + 0.1483 AL - 30) \quad (7)$$

Користувач повинен мати легкий доступ до сидіння з-під стільниці (UTH). Крім того, конструкція

повинна включати між висотою сидіння (SH) та шириною стегна (TT) додаткові 20 мм простору, щоб забезпечити рухливість ніг.

Ширина спинки (BW):

$$BW \geq HB \quad (8)$$

де HB – ширина стегон. Ключовий показник у процесі проектування ширини спинки.

Висота спинки (UEB):

$$UEB \leq SCH \quad (9)$$

де SCH – підлопаткова висота. Важливим антропометричним критерієм для оцінки верхнього краю спинки є підлопаткова висота.

Глибина підстілья (TL):

$$TL \geq BKL \quad (10)$$

де BKL – довжину сідниць та колін. Забезпечує достатній простір для зміни поз або рухів нижньої частини тіла.

Глибина столу (TD):

$$(0.5 SEB + 0.342 AL + 20) \leq TD \leq EFL \quad (11)$$

де SEB – ширина по ліктях сидячи, AL – довжина руки. Для столу потрібен достатній простір, глибина столу повинна дозволяти відведення ліктя під кутом 20° з запасом 20 мм.

Висота робочої поверхні (DH) з урахуванням (1), (4) визначається відносно висоти ліктя сидячої людини (SEH):

$$SEH + SH \leq DH \leq SHE + SH + 5 \text{ cm} \quad (12)$$

Усі параметри (1) – (12) використовуються для антропометричних вимірювань людського тіла в положенні сидячи, що є важливим для проектування ергономічних меблів або робочих місць (рис. 2).

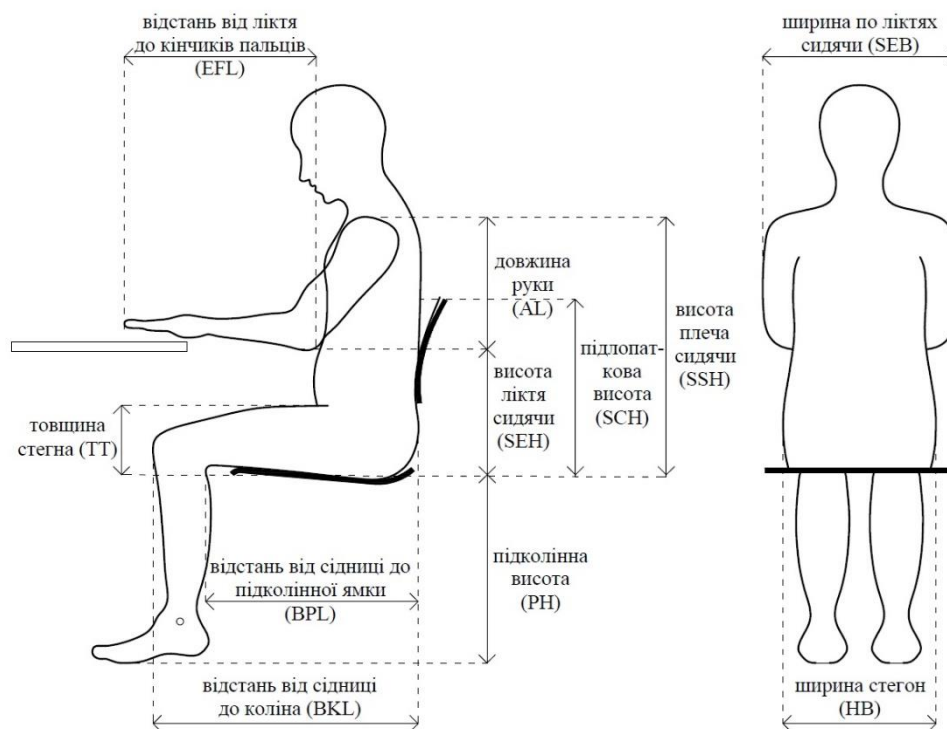


Рис. 2. Антропометрична схема людського тіла в положенні сидячи.

На рис. 3 показана лінія спірання тіла людини, де вигин спинки відповідає форми хребта.

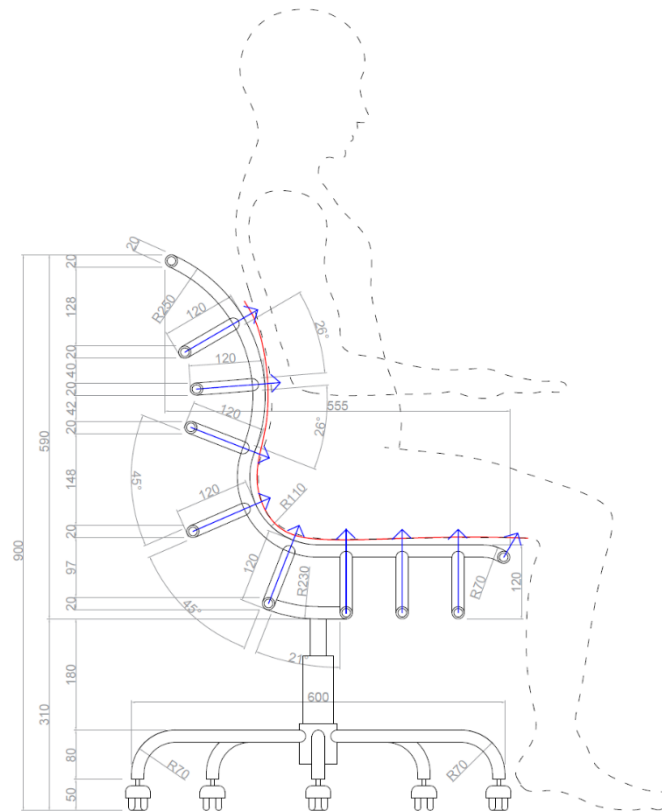


Рис. 3. Бокова проекція лінії спирання тіла людини на крісло

Пропонується каркас стільця виготовлений із нержавіючої сталеві труби. Елементи корпусу будуть формуватися із окремих гнутих частин за допомогою згинального обладнання та зварені між собою, до верхньої поверхні яких прикріплені м'які елементи для підвищення комфорту. Крісло складатиметься з зовнішньої несучої та внутрішньої рухомої частини. Зовнішня конструкція, на яку спирається тіло користувача, буде кріпитися через газліфт до хрестовини з системою роликів через які розподілятиметься навантаження на підлогу. Внутрішня рухома частина складатиметься з послідовно розташованих вібраційних пристроїв, які з'єднані з блоком живлення та блоком керування.

Проектування конструкції крісла з вібраційним механізмом на основі роботи кривошипа з постійним радіусом розташування шипа проводилося за допомогою програмного забезпечення AutoCAD (рис. 6). Після створення креслення конструкції стільця за допомогою AutoCAD (рис. 4), для побудови 3D зображення виробу було використано програмний продукт Google Nano Banana (рис. 5).

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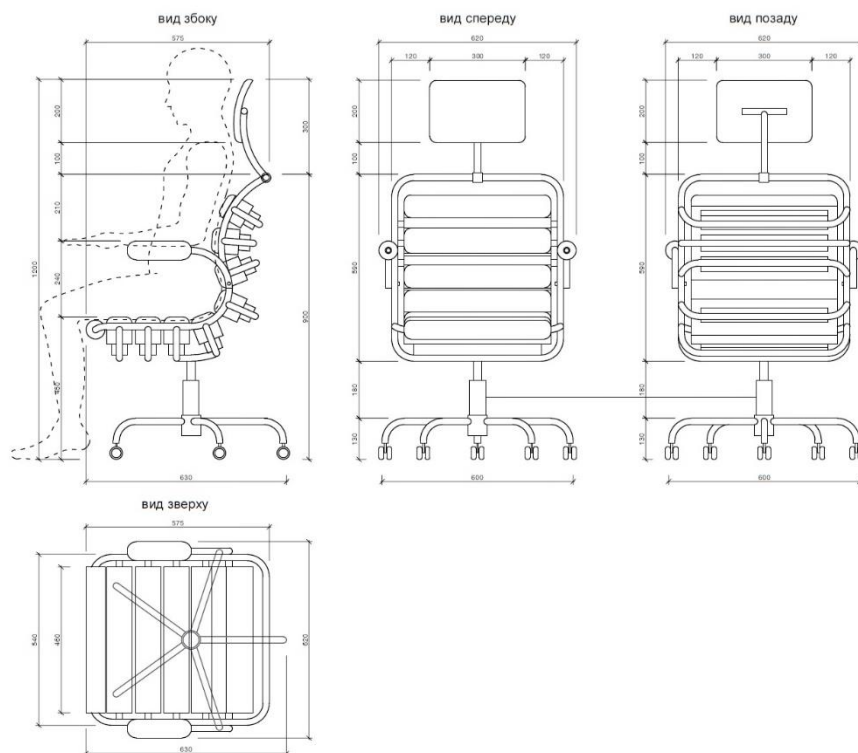


Рис. 4. Проекції вібраційного крісла





Рис. 5. Візуалізація вібраційного крісла

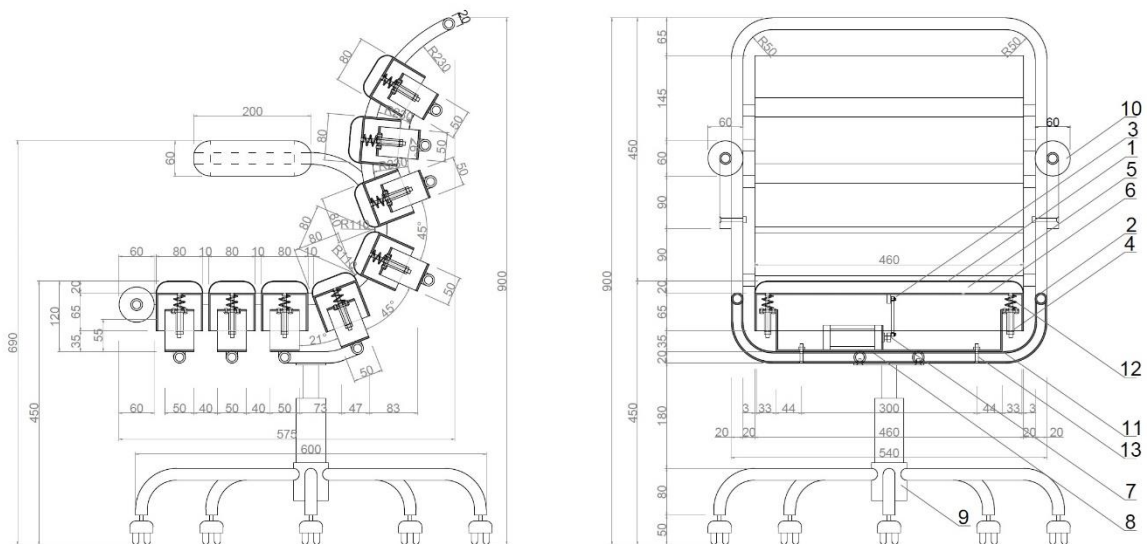


Рис. 6. Конструкція автоматичного вібраційного крісла.

(1. Вініпор. 2. Несуча конструкція. 3. Передавальний стрижень. 4. Лінійний підшипник. 5. Спінена гума. 6. Рухомий елемент вібраційного механізму. 7. Кривошип. 8. Електродвигун. 9. Основа «Павук» для офісного крісла з роликами. 10. Підлокітник. 11. Нерухома частина вібраційного механізму. 12. Пружина. 13. Кріплення вібраційного механізму до несучої рами.)

Серед усіх внутрішніх механізмів – ексцентриково-гвинтовий привід є основним структурним компонентом, що реалізує функцію активації вібраційних рухів для розслаблення м'язів і зняття дискомфорту в тілі.

Механізм передачі має кривошип з постійним радіусом розташування шипа, передавальний стрижень і пружини для набуття вібраційної функції

(рис. 7). Вібрацію крісла можна регулювати вибірково, в залежності від потреб користувача, за допомогою швидкості електродвигунів. Спінена гума середньої жорсткості може посилювати ефективність вібрації по окремих зонах, завдяки розташуванню наборів пристроїв вібраційних механізмів уздовж всієї площини спирання тіла, а саме зони сидиць та спини користувача (рис. 4 та рис. 6).

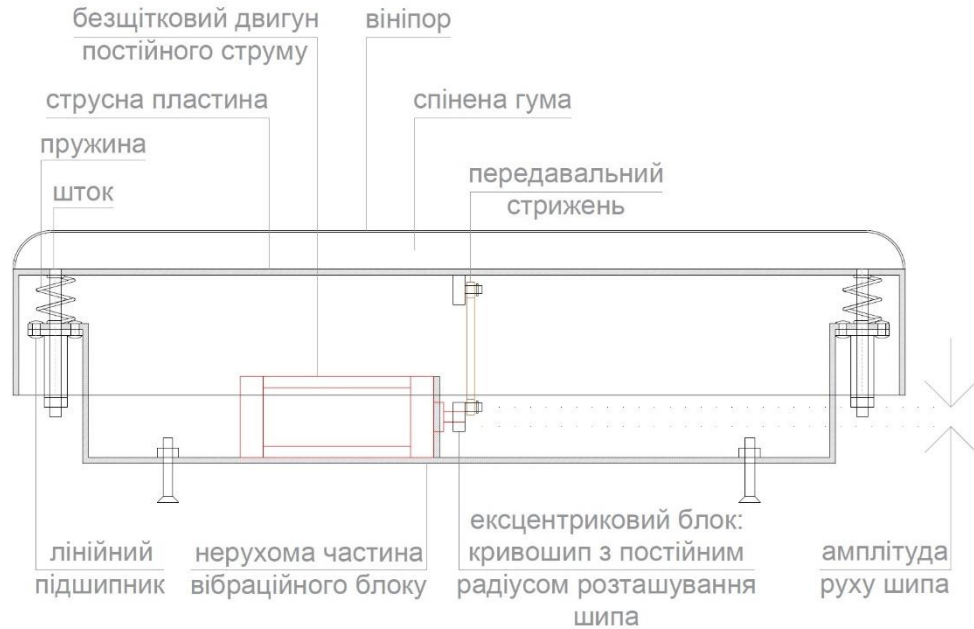


Рис. 7. Наповнення вібраційного блоку

Принцип вібрації крісла. Вібраційна плита, у формі короба, з'єднана з основою, нерухомою частиною, двома пружинами, через напрямний лінійний підшипник і шток. Вібрація відбувається за рахунок кривошипа на який передає обертальний момент безщітковий електродвигун постійного струму, за для створення високошвидкісної вібрації

був обраний двигун потужністю 105 Вт. Зусилля електродвигуна на вібраційну плиту відбувається завдяки передавальному стрижню, який з одного боку з'єднаний із кривошипом з постійним радіусом розташування шипа, а з іншого боку до вібраційного коробу через шарикові підшипники, за для зменшення тертя в усіх рухомих вузлах.

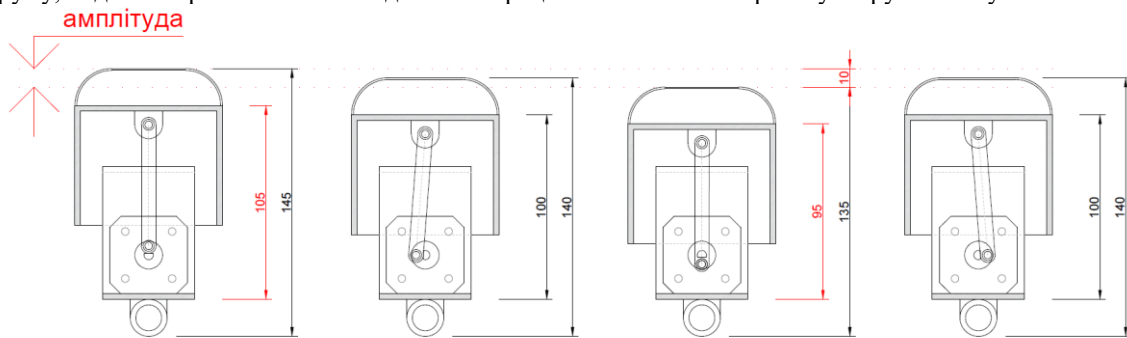


Рис. 7. Положення передавального стрижня при різних положеннях шипа ексцентрикового блоку

Ці частини складають кривошипно-шатунний механізм, за допомогою якого вібраційна плита рухається вгору і вниз. Вібраційні струси в кінцевому

підсумку передаються на тіло людини. Вібраційний блок в розрізі показаний на рис. 8.

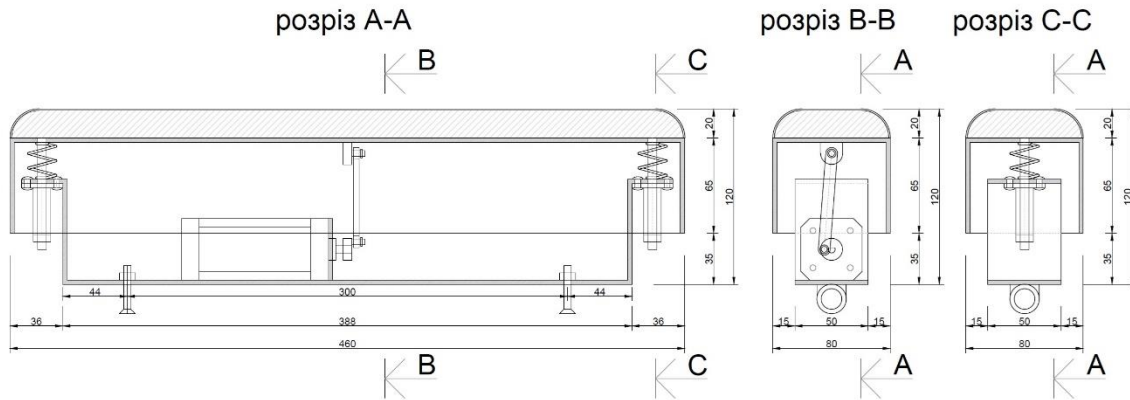


Рис. 8. Вібраційний блок в розрізі

Розрахунок ексцентрикового блоку. Процес вібрації вимагає від механізму передачі великої навантажувальної здатності. Механізм приводу розглядається як основна структура передачі для генерації вертикальних коливань заданої амплітуди (досяг-

нення вібрації вгору і вниз). Принципова схема механізму передачі ланок показує, що механізм в основному складається з кривошипа, шатуна, вібраційної рухомої частини і нерухомої частини. Всі параметри представлено в таблиці 1.

Таблиця 1

| Параметр | Значення | Змінна | Опис |
|--------------------------------|------------|-----------|--|
| Ексцентриситет (радіус шипа) | 5 мм | $L1$ | Половина амплітуди руху |
| Довжина передавального стрижня | 65.5 мм | $L2$ | Довжина шатуна |
| Радіус штока | 3 мм | R_{rod} | Довжина штока 9 мм |
| Зовнішній радіус ексцентрика | 70.5 мм | $R1$ | Радіус великого півкола блоку |
| Радіус валу (шипа) | 3 мм | $R2$ | Внутрішній радіус посадки (діаметр 6 мм) |
| Ширина (товщина) ексцентрика | 5 мм | L | Осьова довжина ексцентрикового блоку |
| Висота нерухомої частини | 72 мм | H | Габарит корпусу |
| Номинальні оберти двигуна | 4000 об/хв | n_{rpm} | Номинальна потужність 105 Вт |

Перевірка габаритної умови висоти

Сума довжин кривошипа та шатуна повинна бути меншою за висоту нерухомої частини:

$$L1 + L2 < H \quad (13)$$

Підставимо значення:

$$5 \text{ мм} + 65.5 \text{ мм} = 70.5 \text{ мм}$$

Оскільки $70.5 \text{ мм} < 72 \text{ мм}$, умова виконується. Механізм має запас у 1.5 мм для вільного обертання в межах нерухомої частини блоку.

Амплітуда руху

Амплітуда (повний хід) визначається як $2 \times L1$:
 $A = 2 \times 5 \text{ мм} = 10 \text{ мм}$

Це повністю збігається з нашими даними: при нижньому положенні висота блока становить 135 мм, а при верхньому – 145 мм ($145 - 135 = 10 \text{ мм}$).

Розрахунок механізму вібрації ексцентрикового колеса

Для ефективної безперервної вібрації відцентрова сила F має подолати розрахункову вагу системи $G = 1500 \text{ Н}$.

Визначення швидкості та щільності

Для безщіткового двигуна *Cloudray Nema17* (105 Вт) номінальна швидкість становить 4000 об/хв.

Переведемо в оберти на секунду (n):

$$n = 4000/60 \approx 66.67 \text{ грс}$$

Щільність сталі $\mu = 7850 \text{ кг/м}^3$.

Розрахунок відцентрової сили

Використовуємо формулу для напівкруглого ексцентрика:

$$F = \frac{8}{3} \pi^2 (R_1^3 - R_2^3) L \mu n^2 \quad (14)$$

де F – відцентрова сила, Н; R_1 , R_2 – радіуси зовнішній і внутрішній, відповідно, м; L – довжина елемента, м; μ – коефіцієнт, що характеризує середовище або матеріал; n – частота обертання або кількість обертів.

1. Геометричний фактор, який враховує об'ємний розподіл маси користувача:

$$R_1 = 0.0705 \text{ м}, R_2 = 0.003 \text{ м}$$

$$(0.0705^3 - 0.003^3) = 0.0003501 - 0.000000027 \approx 0.00035 \text{ м}^3$$

Підстановка значень у (14) дозволить отримати відцентрову силу:

$$F = \frac{8}{3} \times (3,14159)^2 \times 0,00035 \times 0,005 \times 7850 \times (66,67)^2 =$$

$$F \approx 26.219 \times 0.00035 \times 0.005 \times 7850 \times 4444.89$$

$$F \approx 0.3614 \times 4444.89 \approx 1606.4 \text{ Н}$$

Верифікація сили. Проведемо перевірку точності виконаних розрахунків шляхом порівняння з отриманих результатів з еталонними (теоретичними) значеннями.

Отримана сила $F \approx 1606.4$ Н перевищує необхідне значення $G = 1500$ Н. Це означає, що попри компактні розміри ексцентрика (5 мм), великий радіус ($R_1 = 70.5$ мм) та високі оберти двигуна забезпечують достатню інерційну силу для вібрації крісла з користувачем.

Частота вібрації при 4000 об/хв становить:

$$f = 4000/60 \approx 66.67 \text{ Гц}$$

Це відповідає верхній межі діапазону *Whole-Body Vibration* (15 – 70 Гц), що характерно для інтенсивних вібротренажерів. Потужність двигуна 105 Вт є достатньою, оскільки середнє споживання подібних систем у SolidWorks симуляціях складає близько 70–90 Вт.

Висновки

Перевірочний розрахунок підтвердив, що обрана геометрична конфігурація та параметри сили забезпечують стабільну роботу механізму вібраційного крісла в межах заданих експлуатаційних навантажень. Також, створена модель адаптивного крісла підтверджує:

1. Геометричну сумісність двох механізмів. Механізм з шатуном 65.5 мм та кривошипом 5 мм ідеально вписується у корпус висотою 72 мм.

2. Динамічну ефективність прикладеної сили, а саме, наскільки результативно прикладене зусилля (або просто коливання) виконує свою цільову функцію при мінімальних енергетичних витратах, а саме: відцентрова сила 1606 Н є достатньою для подолання інерції системи.

3. Доведено відповідність приводу технічним, ергономічним та функціональним аспектам, а саме здатність запропонованого вібраційного вузла генерувати амплітуду та частоту коливань, які сумісні із фізіологічними потребами користувача. Безшлітковий двигун потужністю 105 Вт забезпечує необхідний крутний момент для обертання ексцентрика заданого радіуса на високих обертах.

Висновки та перспективи досліджень. Розроблено дизайн вібраційного крісла, яке забезпечить інтенсивний вплив у режимі вібрації всього тіла. Робоча частота 66,7 Гц з амплітудою 10 мм дозволяють не лише знімати втому і м'язову напругу для маломобільних людей, а й стимулювати метаболічні процеси у м'язах, що є критично важливим для людей із сидячим способом життя та ще мають терапевтичний вплив.

Попри компактні габарити блоку, він генерує відцентрову силу 1606 Н, що дозволяє впевнено долати інерцію маси користувача (стандарт розрахунку – 65 кг на один блок, у нас 4 блока – 260 кг!) та елементів конструкції крісла. Це забезпечує відчу-

тну вібрацію, навіть через товсті шари оббивки, гарантуючи динамічну стабільність. Поєднання механізму з демпфуючими шарами вініпору та спіненої гуми дозволить кріслу працювати м'яко, поглинаючи зайвий механічний шум і запобігаючи різким ударам штока, що зробить експлуатацію виробу комфортною для тривалого використання.

Отже, крісло може поповнити вже існуючі автоматизовані засоби реабілітації, які поєднують функції меблів та фізіотерапевтичного обладнання. Подальший розвиток даного вібраційного пристрою та крісла в цілому має декілька перспективних напрямків, наприклад, інтеграція «розумних» технологій та штучного інтелекту в систему керування. Застосування датчиків тиску забезпечить можливість динамічного моніторингу антропометричної конфігурації тіла користувача в режимі реального часу, а саме відстежувати позу користувача та надавати вібросигнали-нагадування про необхідність змінити положення.

У подальшому дослідження можуть бути спрямовані на заміну стандартної гуми на високоєфективні поліуретанові еластomers та композити. Використання спеціалізованих матеріалів, таких як *Sylomer* або *Sylodamp*, дозволить ще ефективніше ізолювати механічні шуми та вібрації від каркаса крісла, спрямовуючи весь імпульс виключно на користувача.

Список літератури / References

1. Bovenzi, M.; Hulshof, C.T.J. An updated review of epidemiologic studies on the relationship between exposure to whole-body vibration and low back pain. *J. Sound Vib.* 1998, 215, 595–612.

2. Lee, K.T.; Kim, B.S. Vibration analysis of automobile tire due to bump impact. *Appl. Acoust.* 2008, 69, 473–478.

3. Makhsous, M.; Hendrix, R.; Crowther, Z.; Nam, E.; Lin, F. Reducing whole-body vibration and musculoskeletal injury with a new car seat design. *Ergonomics* 2005, 48, 1183–1199.

4. Kawanabe, K.; Kawashima, A.; Sashimoto, I.; Takeda, T.; Sato, Y.; Iwamoto, J. Effect of whole-body vibration exercise and muscle strengthening, balance and walking exercises on walking ability in the elderly. *Keio J. Med.* 2007, 56, 28–33.

5. Owen N., Sparling P.B., Healy G.N., Dunstan D.W., Matthews C.E. Sedentary Behavior: Emerging Evidence for a New Health Risk. *Mayo Clinic Proceedings*. 2010. Volume 85, Issue 12, pp. 1138–1141. <https://doi.org/10.4065/mcp.2010.0444>

6. Ricci F., Izzicupo P., Moscucci F., Sciomer S., Maffei S., Di Baldassarre A., Mattioli A.V., Gallina S. Recommendations for Physical Inactivity and Sedentary Behavior During the Coronavirus Disease (COVID-19) Pandemic. *Frontiers in Public Health*. 2020, Volume 8, Article 199. <https://doi.org/10.3389/fpubh.2020.00199>

7. Kapur S.S., Stebbins G.T., Goetz C.G. (2012). Vibration Therapy for Parkinson's Disease: Charcot's Studies Revisited. *Journal of Parkinson's Disease*, 2(1), 123–127. <https://doi.org/10.3233/JPD-2012-12079>
8. Tatsuno, J.; Maeda, S. Effect of Whole-Body Vibration Exposure in Vehicles on Static Standing Balance after Riding. *Vibration* 2023, 6, 343-358. <https://doi.org/10.3390/vibration6020021>
9. Tatsuno J, Maeda S. Effect of Whole-Body Vibration Exposure in Vehicles on Static Standing Balance after Riding. *Vibration*. 2023; 6(2):343-358. <https://doi.org/10.3390/vibration6020021>
10. Tatsuno, Junya, and Setsuo Maeda. 2023. "Effect of Whole-Body Vibration Exposure in Vehicles on Static Standing Balance after Riding" *Vibration* 6, no. 2: 343-358. <https://doi.org/10.3390/vibration6020021>
11. Tatsuno, J., & Maeda, S. (2023). Effect of Whole-Body Vibration Exposure in Vehicles on Static Standing Balance after Riding. *Vibration*, 6(2), 343-358. <https://doi.org/10.3390/vibration6020021>
12. The Control of Vibration at Work Regulations 2005. Health and Safety Executive. Available. <https://www.legislation.gov.uk/ukxi/2005/1093/contents/made> (accessed on 22 August 2022).
13. World Health Organization. A Healthy Lifestyle—WHO Recommendations; World Health Organization: Geneva, Switzerland, 2022. Available online: <https://www.who.int/europe/news-room/factsheets/item/a-healthy-lifestyle—who-recommendations> (accessed on 22 August 2022).
14. <https://www.sunrisemedical.com//>
15. <https://ohcomassagechairs.com/>
16. <https://whill.inc/jp>
17. <https://www.permobil.com/en-us>

PHYSICAL AND MATHEMATICAL SCIENCES

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Tsukanova Alisa Olegovna,

Candidate of Physics and Mathematics,

Department of Mathematical Physics and Differential Equations,

National Technical University of Ukraine

«Igor Sikorsky Kiev Polytechnic Institute»,

Pobedy Avenue, 37, 03056, Kiev, Ukraine,

ORCID: <https://orcid.org/0000-0003-0049-3733>

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HOW TO APPLY OPTIMIZATION METHODS OF VARIATIONAL CALCULUS TO CLASSICAL PROBLEMS FROM LINEAR ALGEBRA

Summary.

The given paper presents basic results of analysis of well-known classical Gaussian elimination method of successive elimination of unknowns in solving some set of linear equations and «modern» optimization methods, realized via programming in «Visual Basic for Applications». It is shown that some mathematical problems can be solved with the help of optimization apparatus.

Key words: linear algebra, systems of linear algebraic equations, Gaussian elimination method, Kronecker-Capelli theorem, variational methods, optimization methods, gradient descent method, gradient, minimizer, «Visual Basic for Applications».

Introduction. Roughly speaking, optimization in mathematical sense is difficult process of finding the best decision, with regard to some criterion, from some set of available alternatives. More precisely, mathematical optimization is one branch of applied mathematics, focused on finding the best solution to a problem from a set of possible choices, feasible alternatives, considering specific constraints and objectives. Optimization problems of various types arise in all quantitative disciplines, ranging from computer science, engineering, operations research, and data science to economics, finance, and logistics. For example, by optimizing resource allocation, production processes or logistics, mathematical optimization modeling can reduce costs and improve operational efficiency across workflows.

Active computerization of our intensive life forces mathematical apparatus of optimization to improve and generates new optimization problems. Optimization modeling is rather powerful tool, used, including, in classical mathematics. Today, with active use of computer technologies in our life, we have to admit that computer methods give us innovative way to look at various problems from classical mathematics. Even the simplest problems of linear algebra are not just routine tasks for students and can be considered from a different angle via modern techniques. Linear algebra is, probably, the most fundamental tool for machine learning, providing indeed powerful and versatile framework for representing, analyzing, and manipulating data. Its broad applicability to wide spectrum of machine learning tasks makes it indeed indispensable skill for professionals in the corresponding field. Applied linear algebra allows us to take some different look at many classical problems of mathematics [2], that is demonstrated in this paper.

It presents some results of comparison between well-known traditional method and optimization gradient methods, as well as their variations ([1], [3] – [13]), for solving arbitrary systems of linear algebraic equations. These results have been obtained after testing our own program, written in «Visual Basic for Applications». Namely, we have combined well-known methods from classical algebra and the next two optimization methods: gradient descent method with adapted step selection and gradient descent method with adapted step correction.

Main part. Gradient descent is iterative optimization algorithm for finding one minimum local value of some differentiable function. This is well-known mathematical technique that reaches this minimum by iteratively moving in the direction of the steepest descent, towards minimum value of the function's gradient. The idea behind gradient descent is based on the fact that local minimum of function occurs where its gradient is zero. With the help of this technique, solving an arbitrary system of the form

$$\begin{cases} a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \dots + a_{1n}x_n = b_1, \\ a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \dots + a_{2n}x_n = b_2, \\ a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + \dots + a_{3n}x_n = b_3, \\ \dots, \\ a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + \dots + a_{mn}x_n = b_m, \end{cases}$$

or, equivalently, of the next matrix form

$$A\vec{x} = \vec{b},$$

where

$$A = \begin{pmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \dots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \dots & a_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & a_{m3} & \dots & a_{mn} \end{pmatrix} = A_{m \times n},$$

$$\vec{b} = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \\ \dots \\ b_m \end{pmatrix} = B_{m \times 1},$$

$$\vec{x} = \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ \dots \\ x_n \end{pmatrix} = X_{n \times 1},$$

reduces to finding minimizer, i.e. such vector $\vec{x}^* \in \mathbf{R}^n$, for which

$$\min_{\vec{x} \in \mathbf{R}^n} f(\vec{x}) = f(\vec{x}^*),$$

for the next residual function

$$f(\vec{x}) = (A\vec{x} - \vec{b}, A\vec{x} - \vec{b}) = \|A\vec{x} - \vec{b}\|^2, \quad A \in \mathbf{R}^{m \times n}, \quad \vec{b} \in \mathbf{R}^m, \quad m \leq n,$$

where $\|\cdot\|$ denotes the Euclidean norm, (\cdot, \cdot) – the Cartesian product. This minimum is reached at the solution $\vec{x}^* \in \mathbf{R}^n$ of the system under consideration.

Formally, we take one random starting point $\vec{x} \in \mathbf{R}^n$ and iteratively improve it. More precisely, we iteratively generate some sequence of such points $\{\vec{x}_k\}_{k \geq 0}$ (i.e. some descent trajectory, that is sometimes called a relaxation trajectory, that converges to our solution \vec{x}^*), that

$$f(\vec{x}_{k+1}) \leq f(\vec{x}_k), \quad k \geq 0,$$

according to some iterated scheme.

We have written the program that combines «classical» and «modern» methods for solving arbitrary systems of linear algebraic equations. It consists of two parts: the first is based on the Gaussian elimination method and the second – on using two gradient methods. Screenshots of the program's results, specifically, visual demonstrations of implementation of two gradient methods: gradient descent method with adapted step selection and gradient descent method with adapted step correction, – for the system

$$\begin{cases} x_1 + 3x_2 + 2x_3 = 10, \\ 4x_1 + 3x_2 + 2x_3 = 20, \end{cases}$$

are shown below. Namely, necessary «traditional» result of the Gaussian elimination method: the obtained triangular form of the system, – and «innovative» results of two variational methods: the obtained solution, accuracy of all calculations, and running time of the corresponding method.

The obtained triangular form of the system under consideration has been got with the help of traditional Gaussian elimination method. According to it, the proposed system can be rewritten in the next matrix form

$$\begin{cases} x_1 + 3x_2 + 2x_3 = 10, \\ 4x_1 + 3x_2 + 2x_3 = 20, \end{cases} \leftrightarrow \begin{pmatrix} 1 & 3 & 2 \\ 4 & 3 & 2 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} = \begin{pmatrix} 10 \\ 20 \end{pmatrix} \leftrightarrow A\vec{x} = \vec{b},$$

where $A = \begin{pmatrix} 1 & 3 & 2 \\ 4 & 3 & 2 \end{pmatrix}$ is the corresponding to the system coefficient matrix,

$\bar{A} = \left(\begin{array}{ccc|c} 1 & 3 & 2 & 10 \\ 4 & 3 & 2 & 20 \end{array} \right)$ is the corresponding to the system augmented matrix, and

$\vec{x} = \begin{pmatrix} x_1 \\ x_2 \end{pmatrix}$. With the help of elementary operations for transforming this matrix into row-echelon form, we get the next result

$$\begin{aligned} \left(\begin{array}{ccc|c} 1 & 3 & 2 & 10 \\ 4 & 3 & 2 & 20 \end{array} \right) &= \left(\begin{array}{ccc|c} 1 & 3 & 2 & 10 \\ 4 & 3 & 2 & 20 \end{array} \right) I \rightarrow \left(\begin{array}{ccc|c} 1 & 3 & 2 & 10 \\ 4 & 3 & 2 & 20 \end{array} \right) II - 4 \times I = \\ &= \left(\begin{array}{ccc|c} 1 & 3 & 2 & 10 \\ 4 - 4 & 3 - 12 & 2 - 8 & 20 - 40 \end{array} \right) II = \left(\begin{array}{ccc|c} 1 & 3 & 2 & 10 \\ 0 & -9 & -6 & -20 \end{array} \right) II \rightarrow \\ &\rightarrow \left(\begin{array}{ccc|c} 1 & 3 & 2 & 10 \\ 0 & -9 & -6 & -20 \end{array} \right) II \times (-1) = \left(\begin{array}{ccc|c} 1 & 3 & 2 & 10 \\ 0 & 9 & 6 & 20 \end{array} \right). \end{aligned}$$

The last matrix represents the next equivalent system to the given one

$$\begin{cases} x_1 + 3x_2 + 2x_3 = 10, \\ 4x_1 + 3x_2 + 2x_3 = 20, \end{cases} \leftrightarrow \begin{cases} x_1 + 3x_2 + 2x_3 = 10, \\ 0 + 9x_2 + 6x_3 = 20, \end{cases} \rightarrow \begin{cases} x_1 + 3x_2 + 2x_3 = 10, \\ 9x_2 + 6x_3 = 20. \end{cases}$$

As far as we see,

$$\text{rang} \begin{pmatrix} 1 & 3 & 2 \\ 0 & 9 & 6 \end{pmatrix} = \text{rang} \begin{pmatrix} 1 & 3 & 2 & 10 \\ 0 & 9 & 6 & 20 \end{pmatrix} = 2,$$

thus the system is solvable. Since the obtained rang (two) is less than the given quantity of the arguments (three), there exist infinitely many solutions. Back-substitution yields

$$\begin{cases} x_1 + 3x_2 + 2x_3 = 10, \\ 9x_2 + 6x_3 = 20, \end{cases} \rightarrow \begin{cases} x_1 + 3x_2 + 2x_3 = 10, \\ x_2 = \frac{20 - 6x_3}{9}, \end{cases} \rightarrow$$

$$\begin{aligned} &\rightarrow \begin{cases} x_1 + \frac{3(20-6x_3)}{9} + 2x_3 = 10, \\ x_2 = \frac{20-6x_3}{9}, \end{cases} \rightarrow \begin{cases} x_1 + \frac{20-6x_3}{3} + 2x_3 = 10, \\ x_2 = \frac{20-6x_3}{9}, \end{cases} \rightarrow \\ &\rightarrow \begin{cases} x_1 + \frac{20}{3} - \frac{6x_3}{3} + 2x_3 = 10, \\ x_2 = \frac{20-6x_3}{9}, \end{cases} \rightarrow \begin{cases} x_1 + \frac{20}{3} - 2x_3 + 2x_3 = 10, \\ x_2 = \frac{20-6x_3}{9}, \end{cases} \rightarrow \\ &\rightarrow \begin{cases} x_1 + \frac{20}{3} = 10, \\ x_2 = \frac{20-6x_3}{9}, \end{cases} \rightarrow \begin{cases} x_1 = 10 - \frac{20}{3}, \\ x_2 = \frac{20-6x_3}{9}, \end{cases} \rightarrow \begin{cases} x_1 = \frac{10}{3}, \\ x_2 = \frac{20-6x_3}{9}, \end{cases} \rightarrow \\ &\rightarrow \begin{cases} x_1 = \frac{10}{3}, \\ x_2 = \frac{20-6x_3}{9}, \\ x_3 = x_3, \end{cases} \end{aligned}$$

where $x_3 \in \mathbf{R}$ is free.

According to the proposed optimization methods, we have obtained the next results, demonstrated on the pictures below (fig. 1, fig. 2).

x1=3,332449
x2=1,538976
x3=1,025984

7,7578398502554E-03

0,015625 сек.

Fig. 1. The obtained results of gradient method with adapted step selection

x1=3,331985
x2=1,539338
x3=1,026225

9,98847237550768E-03

0,46875 сек.

Fig. 2. The obtained results of gradient method with adapted step correction

Conclusions. Gradient descent is perspective optimization algorithm used to minimize some function by iteratively moving in the direction of the steepest descent. Optimization modeling is rather powerful tool and is widely applied not only in engineering problems, but is also ideally suited to classical linear algebra. In order to demonstrate it, we have written our own program in «Visual Basic for Applications». It combines well-known traditional method and optimization gradient methods, as well as their variations, for solving arbitrary systems of linear algebraic equations.

References

1. Ахмеров, Р. Р. Методы оптимизации гладких функций / Р. Р. Ахмеров. – Новосибирск: ун-т, 1993. – 100 с.
2. Бейко, І. В. Задачі, методи і алгоритми оптимізації / І. В. Бейко, Б. Н. Бублик, О. Г. Наконечний. – Рівне: НУВГП, 2011. – 624 с.
3. Демидович, Б. Д. Основы вычислительной математики / Б. Д. Демидович, И. А. Марон. – Москва: Наука, 1966. – 664 с.
4. Ермольев, Ю. М. Математические методы исследования операций / Ю. М. Ермольев, И. И. Ляшко, В. С. Михалевич, В. И. Тюптя. – Киев: Вища школа. – 1979. – 312 с.
5. Карманов, В. Г. Математическое программирование / В. Г. Карманов. – Москва: Наука. – 1986. – 286 с.
6. Моисеев, Н. Н. Методы оптимизации / Н. Н. Моисеев, Ю. П. Иванюков, Е. М. Столярова. – Москва: Наука. – 1978. – 351 с.

7. Пиеничный, Б. Н. Численные методы в экстремальных задачах / Б. Н. Пиеничный, Ю. М. Данилин. – Москва: Наука. – 1975. – 319 с.
8. Цуканова, А. О. Вариационный метод градиентного спуска решения систем линейных алгебраических уравнений / А. О. Цуканова. – Польский международный журнал научных публикаций «Colloquium-journal». – Т. 186, № 27, ч. 1. – 2023. – С. 89 – 94. DOI: 10.24412/2520-6990-2023-27186-89-94.
9. Шор, Н. З. Методы минимизации недифференцируемых функций и их приложения / Н. З. Шор. – Киев: Наук. думка. – 1979. – 200 с.
10. Axler, S. Linear Algebra Done Right (Undergraduate Texts in Mathematics) / S. Axler. – Springer, 2015. – 340 p.
11. Strang, G. Introduction to Linear Algebra / G. Strang. – Wellesley, MA: Wellesley-Cambridge Press, 2009. – 585 p.
12. Tsukanova, A. One Variational Method of Solving Classical Problems from Linear Algebra / A. Tsukanova. – International Scientific Journal «Internauka». – V. 151, № 17. – 2023. – P. 43 – 45. DOI: 10.25313/2520-2057-2023-17-9276.
13. Tsukanova, A. One Gradient Descent Method with Adapted Step Correction for Solving Arbitrary Systems of Linear Algebraic Equations / A. Tsukanova. – Polish International Journal of Scientific Publications «Colloquium-journal». – V. 234, № 41. – 2025. – P. 27 – 32. DOI: 10.5281/zenodo.14909959.

PHILOLOGICAL SCIENCES

Ayten Shakir Humbetova

PhD in Philology, Lecturer at the Department of English (for Natural Sciences)

Faculty of Philology, Baku State University, ORCID: 0000-0001-6325-8197

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SEMANTIC DEVIATIONS AND ADEQUACY IN LITERARY TRANSLATION

Abstract

This article provides a comprehensive analysis of the issues related to ensuring adequacy and preventing semantic deviations in the process of literary translation, examined both within a theoretical framework and through practical translation examples. The main objective of the study is to determine to what extent and by which means the semantic structures, authorial intent, stylistic features, and cultural codes of the original text are preserved in translation.

One of the central challenges in translation practice—semantic deviation, that is, the partial or complete alteration, loss, or transformation of meaning—is explored both theoretically and through specific examples drawn from Azerbaijani and world literature. The article reviews both classical and contemporary approaches to translation theory. In this context, conceptual frameworks such as Eugene Nida’s “dynamic equivalence,” Peter Newmark’s “semantic and communicative translation,” and Lawrence Venuti’s notions of “invisibility,” “domestication,” and “foreignization” are analyzed, with particular attention to the semantic choices and cultural adaptation strategies faced by translators.

It is emphasized that adequacy in literary translation must be achieved not only at the lexical level but also within contextual and cultural depth. From this perspective, the role of the translator extends beyond the mere transfer of linguistic units and encompasses the function of an intercultural mediator.

The study conducts a comparative analysis between examples from Azerbaijani literature and selected works from world literature, examining the level of adequacy in translations and identifying instances of semantic deviation. Special attention is given to how the internal rhythm, cultural specificity, and stylistic features of the original texts are preserved in their translated forms.

In conclusion, the article demonstrates that while semantic deviations are an inherent component of the literary translation process, their proper management in accordance with the source text and the target audience depends directly on the translator’s professional competence and theoretical background. A well-developed translation strategy facilitates both the preservation of semantic adequacy and the comprehension of the deeper cultural and stylistic layers of the text for the target audience. In this regard, translation is viewed not only as a transfer of language but also as a transfer of culture.

Keywords: *adequacy, semantic deviation, literary translation, text transformation, cultural code, context, equivalence*

Introduction

Translation activity is a complex, multifaceted, and multi-layered process that functions as a bridge between languages and cultures. It is not limited to performing a communicative transfer at the linguistic level; it also entails the transmission of social, cultural, and ideological content from one context to another. In this sense, translation practice goes beyond merely finding semantic correspondences; rather, it is a dynamic creative process accompanied by the interpretation, editing, and, at times, reconstruction of meaning.

Literary translation, in particular, represents the most sensitive and nuanced form of this process. Here, the translator’s task is not only to convey the semantic load of the text but also to preserve, as faithfully as possible, its aesthetic and emotional layers, style, rhythm, intonation, and cultural values. This task also aims to evoke in the reader an experience analogous to that of the original text. However, intercultural differences, the specificity of linguistic systems, and shifts in context make the fulfillment of this task highly challenging.

Literary texts typically possess multilayered semantic structures that extend beyond the surface level

of language, encompassing intertextual, psychological, historical, and cultural codes. Under such complex conditions, the translator bears responsibility not only for transferring units of meaning but also for adequately conveying the symbols, metaphors, cultural references, and connotations that constitute the text. This demonstrates that adequacy cannot be reduced to mere lexical equivalence; rather, it should be understood as a broader concept encompassing functional and cultural adequacy.

Within this framework, adequacy and semantic deviation emerge as central theoretical and practical categories in the translation process. Adequacy generally reflects the extent to which the translated text corresponds to the source text and preserves its functional purposes and meanings. Most translation theorists (e.g., Nida, 1964; Newmark, 1988; Reiss, 2000; Toury, 1995; Venuti, 1995) regard adequacy as a key criterion of translation quality, while also emphasizing its contextual variability and relativity. In many cases, complete adequacy is practically unattainable, requiring the translator to reconsider and reestablish priorities.

Some semantic deviations arise from structural differences between languages—for instance, the need to explicate dense metaphorical expressions in English when translating into Azerbaijani, or the absence of equivalent cultural connotations in the target language. Others may result from the translator's ideological or poetic intentions, the need to adapt to the target audience, issues of censorship, or the demands of aesthetic transformation (Jakobson, 1959; Bassnett & Lefevere, 1990).

The translator's worldview, translation strategy, level of professionalism, and theoretical stance play a crucial role in this process. For example, Venuti's model of the "invisible translator" advocates for the translator's transparency within the text, whereas post-structuralist approaches regard the translator as a subject who rewrites the text. These differing perspectives lead to contrasting positions on whether semantic deviations should be minimized or accepted.

In literary translation practice, semantic deviations are sometimes regarded as a form of creative transformation. For instance, a translator may introduce semantic changes in order to preserve the poetic structure. In certain cases, such transformations can endow the translated text with new aesthetic value, allowing it to function as a "second original." From this perspective, adequacy does not always imply strict lexical or semantic equivalence but may also involve functional and aesthetic adaptation.

Taking all these factors into account, it becomes evident that adequacy and semantic deviation in translation are not merely technical issues but also epistemological and ethical concerns (Baker, 2011; Venuti, 1995). The translator's responsibility lies not only in rendering the text accurately but also in preserving and enriching the reader's cultural and emotional experience. This requires viewing translation not as a static technology but as an interdisciplinary and creative field of activity (Berman, 1985, p. 194).

In addition to shedding new light on the theoretical and practical aspects of literary translation, this study emphasizes the relevance and significance of translation activity within the context of Azerbaijani literature. It aims to demonstrate that literary translation is not merely a mechanism of linguistic transfer but also a form of cultural dialogue and creative practice.

Degree of Problem Development

The issues of adequacy and semantic deviation in the translation process have been extensively studied in global scholarly literature for many years through various methodological approaches. However, a comprehensive and systematic examination of these problems within the context of Azerbaijani literature, particularly in comparison with world literature, remains relatively underexplored.

Eugene Nida expanded the concept of adequacy through the notion of "dynamic equivalence," emphasizing that an ideal translation should produce the same emotional and contextual effect on the target audience as the original text does on its readers (Nida, 1964, p. 159; 2001, p. 24). Hans Vermeer's Skopos theory, on the other hand, foregrounds the purpose-oriented nature of translation, interpreting semantic deviations in some

cases as functionally justified adaptations (Vermeer, 1989, p. 178). This approach, developed in collaboration with Katharina Reiss, highlights the importance of genre-functional equivalence in literary translation (Reiss & Vermeer, 1984, p. 45).

Lawrence Venuti (1995, p. 56), in *The Translator's Invisibility*, argues that semantic deviations often serve to maintain the translator's invisibility and are regulated by the ideological demands of the target culture. Similarly, Antoine Berman (1985, p. 120), in *Translation and the Trials of the Foreign*, suggests that semantic deviations frequently arise from ethnocultural deformation tendencies within the translation process.

Post-structuralist translation studies, particularly those conducted by Susan Bassnett and André Lefevere (1990, p. 33), demonstrate that translation is not merely a transfer of language but a process of cultural rewriting. Jeremy Munday (2001, p. 76), in *Introducing Translation Studies*, classifies different types of adequacy and semantic equivalence, distinguishing between contextual, stylistic, and functional deviations. Peter Newmark (1988, p. 67), in *A Textbook of Translation*, associates adequacy with the transmission of information while also emphasizing the importance of preserving emotive and connotative elements in literary translation.

Within Azerbaijani literary scholarship, this issue has been addressed by researchers such as Abulfat Valiyev, Ramiz Asgar, and Ekber Aghayev; however, these studies are largely limited to the linguistic analysis of specific translation examples (Valiyev, 2011, p. 245). Rashid Efəndiyev (2008, p. 52) has focused on semantic losses and additions in Azerbaijani translations, particularly highlighting the influence of ideological filters in translations from Western literature.

Scott (2000, p. 88), in *Translating Baudelaire*, demonstrates that semantic deviations related to the transformation of metaphorical structures are inevitable in poetry translation. Roman Jakobson, in his seminal article *On Linguistic Aspects of Translation* (1959, p. 232), asserts that semantic deviations arise as a result of code-switching and cannot be entirely eliminated. More recently, Mona Baker (2011, p. 143), in *In Other Words*, provides a detailed account of how semantic equivalence shifts across syntactic, lexical, pragmatic, and ideological levels.

Research conducted on this theoretical basis shows that the problem of semantic deviation is not merely a technical aspect of translation but a complex phenomenon operating at ideological, cultural, and discursive levels. Deviations in translation arise not only from structural differences between languages but also from the influence of diverse cultural contexts, social relations, ideological tendencies, and the expectations of the target audience. These factors allow translation to be understood not simply as the transfer of texts through language, but as a process of dialogue and interaction between cultures.

Nevertheless, despite this rich theoretical framework, the study of adequacy and semantic deviation in relation to the unique poetics of Azerbaijani literature, its national-cultural codes, and the specific stylistic and aesthetic features of the language remains insufficiently

developed. The lexical-semantic and contextual characteristics of the Azerbaijani language, along with its symbolic and metaphorical cultural system, introduce additional complexities into the translation process. Therefore, the nature and forms of deviations arising in the translation of Azerbaijani literature, as well as their ideological and aesthetic implications, require more extensive and contextually grounded investigation.

Thus, the application of existing theoretical models to Azerbaijani literary texts, their adaptation to local linguistic and cultural specificities, and the development of new research in this field are essential not only for the advancement of translation studies but also for ensuring the accurate and comprehensive international recognition of Azerbaijan's literary heritage. In this regard, the study of adequacy and semantic deviation within the context of Azerbaijani literature is both theoretically significant and practically relevant.

Aim and Objectives

The primary aim of this article is to provide a comprehensive and in-depth analysis of the nature, causes, and consequences of adequacy issues and semantic deviations arising in the translation process, based on examples from Azerbaijani and world literature. Taking into account that literary translation is not only a linguistic activity but also a complex communicative process operating across cultural, ideological, and aesthetic dimensions, the study seeks to evaluate the challenges encountered in this process on a scientific basis and to propose methodological approaches to address them.

One of the key objectives of the research is to investigate how the concepts of "adequacy" and "semantic deviation" have been conceptualized within translation theory and the theoretical contexts in which they are employed. To this end, the approaches of leading translation theorists such as Nida, Newmark, Venuti, Bassnett, and Berman are comparatively examined, and the practical implications of these concepts in the context of literary translation are demonstrated. The article also empirically analyzes how these notions manifest across different languages and intercultural translation contexts, drawing on selected examples from Azerbaijani and world literature.

Another important objective is to identify the nature of semantic deviations occurring in the translation process—such as loss of meaning, addition, and transformation—determine the linguistic and cultural structural differences that give rise to them, and examine their impact on the functionality and aesthetic integrity of the translated text. For this purpose, metaphorical systems, cultural symbols, syntactic structures, and contextual codes in translated texts are analyzed.

Furthermore, through comparative analysis of specific literary examples, the article demonstrates the conditions under which adequacy is preserved or violated in translation, while also examining the causes and consequences of such deviations. The aim is to address the central dilemma of translation—the tension between fidelity to the source text and adaptation to the target audience—and to propose ways in which this dilemma can be resolved.

In addition, the article aims to propose a theoretically grounded and practically relevant methodological model for contemporary translation practice. This includes developing a typology of adequacy and deviation, evaluating the effectiveness of various translation strategies (such as literal translation, adaptation, domestication, and foreignization), and analyzing the role and responsibility of the literary translator.

Finally, as a scientific contribution, this study offers, for the first time within the Azerbaijani translation context, such a broad and comparative approach to the issues of adequacy and semantic deviation. It seeks to promote a more flexible and context-sensitive understanding of these concepts and to contribute to the advancement of translation theory. The article is intended to provide a valuable theoretical and analytical framework for researchers, educators, students, and professional translators working in the field of literary translation.

Methodology

The methodology of the article is based on an interdisciplinary approach grounded in the principles of modern translation studies and comparative literary analysis. Both theoretical and empirical methods are employed, allowing for a multi-layered examination of the concepts of adequacy and semantic deviation.

At the initial stage, a theoretical and methodological framework is established through the review of key concepts in translation theory. These include Eugene Nida's model of dynamic equivalence, Peter Newmark's distinction between semantic and communicative translation, Lawrence Venuti's strategies of domestication and foreignization, Susan Bassnett's intercultural approach, and Antoine Berman's notion of deformation tendencies. Based on these approaches, the terminological contours and practical significance of adequacy and deviation are defined.

At the next stage, an empirical analysis is conducted through the comparative examination of selected original and translated texts from Azerbaijani and world literature. The analysis includes works by both classical and modern authors, such as Ulysses by James Joyce, *The Metamorphosis* by Franz Kafka, *Anna Karenina* by Leo Tolstoy, as well as translations of works by Chingiz Abdullayev and Anar, and Azerbaijani literary texts translated into English and Russian. Specific instances of semantic deviation—such as loss of meaning, additions, shifts in connotation, and transformations of symbolic codes—are identified and analyzed in terms of their underlying causes.

Linguistic and structural-semantic methods are employed to examine how lexical units, syntactic constructions, and contextual elements change during the translation process. This approach enables the derivation of objective conclusions regarding structural differences and their impact on meaning.

In addition, hermeneutic and intercultural approaches are applied to analyze how the translator interprets the original text, transforms its cultural codes, and employs various strategies to adapt it for the target audience. This allows for an assessment of the translator's subjectivity and ideological positioning in shaping translation quality.

The study also utilizes discourse analysis to investigate the transformation of speech acts, metaphors, and socio-cultural markers within translated texts, evaluating their alignment with the poetics and functional context of the source text.

Finally, a typological classification is developed, identifying categories and levels of adequacy and deviation (lexical-semantic, syntactic, stylistic, and contextual). Based on this classification, the findings are systematized and generalized.

Thus, the methodology of the article integrates theoretical, analytical, and comparative approaches, enabling a comprehensive exploration of the multilayered nature of the translation process. This approach demonstrates clearly how adequacy and semantic deviation emerge not only at the theoretical level but also within the context of real translation practice.

Main Part

Translation activity, as a complex process that ensures the transfer of meaning between languages and cultures, has generated extensive discussion in both theoretical and practical domains. One of the most essential categories determining the quality of translation is adequacy. At the same time, semantic differences and changes arising in the translation process are evaluated as semantic deviation. The precise definition and analysis of these concepts are important for understanding the nature of translation and the complexity of translation at different levels.

In translation theory, the term adequacy primarily refers to the principle of preserving, as accurately and closely as possible, the meaning, function, intention, and style of the source text in the translated text. In other words, adequacy is a criterion that measures the degree of correspondence between the translation and the source text. When first widely analyzed, this category was considered a subjective and multilayered phenomenon that varies depending on the purpose and context of the translation.

American linguist and translator Eugene Nida expanded the concept of adequacy with the term “dynamic equivalence,” emphasizing that an ideal translation should produce the same emotional and contextual impact on the reader as the source text does (Nida, 1964, 159; 2001, 45). This approach prioritizes conveying meaning and function to the reader rather than maintaining word-for-word correspondence.

On the other hand, Peter Newmark divided the translation process into communicative and semantic translation, distinguishing communicative translation as conveying the social function of the text clearly to the reader, while semantic translation aims to preserve the linguistic and cultural-literary features of the original as much as possible (Newmark, 1988, 261). According to Newmark’s theory, adequacy depends on the balance between these two approaches and the purpose of translation. These approaches demonstrate the multilayered and dynamic nature of adequacy and deviation in translation (Nida, 1964, 159; Newmark, 1988, 261).

Moreover, adequacy has been examined from various perspectives by other scholars in translation studies. For instance, Mona Baker presents adequacy as

a multifaceted category adapted to the communicative purpose of translation, the genre of the text, and the target audience. This approach emphasizes that the translator’s decisions are context- and function-dependent.

Consequently, adequacy in translation theory is considered an ideal state, namely the highest level of semantic, functional, and stylistic correspondence between the translation and the source text. However, in translation practice, especially in literary texts, achieving this ideal state is often impossible, since there are differences and contradictions at various levels between the specific features of both languages and cultures.

Meaning loss and changes in the translation process—namely semantic deviations—are inevitable. These may arise both from structural differences between languages and from the interpreter’s choices. Various types of semantic deviation have been identified in translation theory, and these types serve as key tools for analyzing variability at the textual level and the content of translator decisions.

The most commonly accepted types of semantic deviation are as follows:

a) Loss: This type of deviation is characterized by the complete or partial omission of certain information, meaning, or stylistic features present in the source text. Loss may occur both at the literal level and in the emotional and aesthetic layers of the text. For example, the failure to convey a specific metaphor or cultural context in translation can be considered loss. Loss sometimes occurs due to technical constraints faced by the translator or the limited expressive possibilities of the target language.

b) Addition: In this case, the translator introduces information, explanations, or comments that are not present in the source text but are intended to facilitate comprehension or clarify context for the reader. Addition may be applied to ensure syntactic compatibility or to resolve cultural mismatches. However, this may alter the simplicity of the original and the message intended for the reader.

c) Shift (Transformation): The term shift refers to changes at the semantic or syntactic level. It involves restructuring the meaning of the original text in translation along with structural modifications. Syntactic transformations may include changes in sentence structure or word order. Semantic transformations, on the other hand, involve changes in layers of meaning or the reinterpretation of certain expressions. Transformations may be necessary both to adapt to structural differences between languages and to bridge intercultural distinctions.

d) Compensation: Compensation refers to the technique of replacing losses and deviations that arise in the translation process by other means, such as additional explanations, synonyms, or stylistic devices. It represents a strategic approach used by the translator to preserve the adequacy of the text. Compensation depends on the translator’s creativity in balancing both meaning loss and stylistic changes.

These types of semantic deviation not only alter the meaning of the translation but also determine how

the cultural and aesthetic values of the text are preserved or transformed. Therefore, a complex and dynamic relationship exists between adequacy and deviation. In order to ensure adequacy, the translator sometimes has to accept deviations and, at other times, use additional methods to minimize them. This balance determines the quality of the translation and the impact of the message conveyed to the reader.

Anar's novella "White Ram, Black Ram" is one of the works of Azerbaijani literature distinguished by its symbolic richness and deep philosophical and cultural layers. The metaphorical language and fatalistic worldview in the work reflect the aesthetic and ideological elements of national culture. During the translation process, conveying such culturally and semantically loaded expressions adequately into other languages creates significant difficulties. For this reason, the following short phrase taken from Anar's work is particularly important from the perspective of translation practice.

The original sentence in Azerbaijani reads: "Bu dünyada ağ qoç da var, qara qoç da... Hansı səninkidir – sən bilirsən."

In this expression, "white ram" and "black ram" function as symbolic images representing different choices in life, dualism, and sometimes the inevitability of fate. The fatalistic approach—"you know which is yours"—emphasizes the predetermined nature of life to a certain extent and suggests that human beings have limited control over their choices and will. This sentence evokes deep moral and existential reflections in the reader and carries Azerbaijani worldview as a cultural code.

From a translation perspective, different levels of adequacy and deviation can be observed in the Russian and English versions of the phrase.

The Russian translation is: "В этом мире есть и белый баран, и черный... Какой твой – решай сам."

Although the expressions "белый баран" and "черный" are close to the symbolism of "ağ qoç" and "qara qoç," some important nuances are lost. The word "баран" in Russian simply denotes the animal and does not convey the metaphorical load with the same strength. In Azerbaijani, "qoç" is also associated with attributes such as strength, struggle, and leadership, which are less expressive in "баран." Moreover, the phrase "Какой твой – решай сам" does not fully reflect the fatalistic idea. The emphasis here is on "decide yourself," which suggests freedom of choice rather than fatalism. Thus, in the Russian translation, the emotional and philosophical weight of the fatalistic worldview weakens, and the cultural context of the text changes to a certain extent.

The English translation reads: "There are white rams and black rams in this world... You know which is yours."

In the English version, the expressions "white rams" and "black rams" reflect the symbolism of "ağ qoç" and "qara qoç" more accurately, since the word "ram" corresponds directly to "qoç" and carries a closer symbolic meaning than the Russian "баран." Nevertheless, the phrase "You know which is yours" only partially conveys the fatalistic element. While it

preserves the meaning of "you know," the emotional and philosophical depth is somewhat weakened. The sentence appears to give the reader a sense of choice and does not fully encompass the fatalistic concept of destiny. Additionally, fatalism functions differently in English contexts, and extra linguistic means would be required to reinforce the fatalistic tone of this phrase.

The comparative analysis of all three versions demonstrates that the issue of adequacy is not limited to lexical and syntactic correspondence but is also closely related to the transmission of cultural context and the philosophical-aesthetic weight of the text. The original Azerbaijani phrase conveys the metaphorical mode of thinking and fatalistic worldview of national culture not only through symbolic expressions but also through emotional layers. The loss or weakening of these layers reduces the adequacy of the translation.

In the Russian translation, the main shortcoming in reflecting the fatalistic worldview is evident in the expression "решай сам." This phrase emphasizes freedom of will rather than fatalism and offers the reader a sense of choice. However, in the Azerbaijani original, the outcome of the choice is framed more within the boundaries of fate and inevitability. Here, the cultural-contextual difference alters the translation outcome and weakens the original philosophical meaning of the text.

The English translation preserves the symbolic expressions more successfully but still weakens the fatalistic aspect. The phrase "You know which is yours" suggests that the choice belongs to the reader and diminishes the sense of fatalism. Since the concepts of fatalism and destiny are expressed with different semantic nuances in English, additional contextual elements would be required to preserve the depth of this phrase.

Overall, this analysis shows that adequate literary translation is not limited to word equivalence but also requires the transfer of cultural context, symbolism, and philosophical layers of meaning. For the translator, this involves maintaining a delicate balance among multilayered and sometimes contradictory meanings and presenting the reader with an experience close to the original. In such cases, semantic deviations are inevitable, and finding the balance between adequacy and deviation becomes the primary objective of translation.

Franz Kafka's 1915 work *Die Verwandlung* ("The Metamorphosis") is a fundamental example in world literature that expresses themes of modernism and existentialism through deeply metaphorical language. The famous opening sentence—"Als Gregor Samsa eines Morgens aus unruhigen Träumen erwachte, fand er sich in seinem Bett zu einem ungeheuren Ungeziefer verwandelt."—carries the core philosophical and existential significance of the work (Kafka, 1915/1996).

The expression "ungeheures Ungeziefer" in the original German, although it can be translated literally as "gigantic insect," carries not only a biological meaning but also a profound metaphorical and symbolic significance in Kafka's literature. In classical German, the word "Ungeziefer" generally refers to

“vermin,” “repulsive creature,” or “noxious pest,” and functions here as a symbol of Gregor Samsa’s inner degradation, social isolation, and alienation from humanity. This image embodies the existential transformation of the individual within Kafka’s aesthetic of fear and absurdity.

In the Azerbaijani translation by Asad Cahangir, the expression is rendered as follows: “Qreqor Samsa bir səhər narahatedici yuxulardan ayılında gördü ki, yatağında nəhəng bir həşəratat çevrilmişdir.”

Here, the phrase “nəhəng bir həşərat” foregrounds the biological meaning and presents a narrower and more concrete interpretation of Kafka’s ambiguous and metaphorical concept of “Ungeziefer.” This represents an example of semantic deviation in the form of transformation.

Loss of symbolic and metaphorical meaning: In German, the word “Ungeziefer” is not understood as a specific type of insect but rather as any repulsive, socially and existentially isolated creature rejected by its environment. It symbolizes Gregor’s position within society and family, his internal conflicts, and his alienation from humanity. In the Azerbaijani translation, however, the phrase “giant insect” creates a more limited and realistic image. This weakens the Kafkaesque atmosphere of ambiguity, loneliness, and absurdity, reducing the symbolic layers in the reader’s imagination.

Reduction of metaphysical and existential layers: In Kafka’s work, Gregor Samsa’s transformation is not only physical but also psychological and philosophical. The image of “Ungeziefer” conveys meanings of existential isolation, moral decay, and social alienation. Emphasizing the biological image in translation simplifies this multilayered meaning and leads to a weakening of Kafka’s metaphysical dimension.

The role of language and culture in translation: In Azerbaijani, the word “həşərat” directly refers to insects in general and, although it may carry negative or repulsive connotations, it does not possess the symbolic and moral resonance embedded in Kafka’s use of “Ungeziefer.” Thus, due to linguistic and cultural differences as well as terminological limitations, the translation struggles to fully convey the philosophical depth of the original work.

Semantic deviation and transformation: In this example, the semantic deviation in translation is not limited to lexical choice but also leads to changes in the semantic, cultural, and philosophical structure of the text. Rendering “Ungeziefer” as “giant insect” reduces the ambiguity, absurdity, and existential fear present in the original. This represents a transformation-type semantic deviation—where certain meanings of the original text manifest differently within another linguistic and cultural framework.

The translation of the expression “ungeheures Ungeziefer” in the Azerbaijani version of Kafka’s *The Metamorphosis* is a significant example illustrating translation difficulties between language and culture as well as the nature of semantic deviations. The loss of symbolic and metaphorical layers in translation results in a weakening of the philosophical and existential weight of the original work. This clearly reveals the

central dilemma faced by translators—the losses and changes that occur when conveying multilayered meanings from one language and culture into another. In such cases, the translation process requires finding a delicate balance between adequacy and deviation so that the spirit of the original is preserved while adapting to the cultural context of the target language.

When semantic deviation and adequacy in literary translation are examined through specific examples, the multilayered nature of interlingual and intercultural transformation becomes more evident. In this respect, analysis based on examples translated into different languages demonstrates how the translation process seeks a balance between semantic fidelity and poetic value.

In the famous opening sentence of Franz Kafka’s *The Metamorphosis*—“Als Gregor Samsa eines Morgens aus unruhigen Träumen erwachte, fand er sich in seinem Bett zu einem ungeheueren Ungeziefer verwandelt”—the expression “ungeheures Ungeziefer” symbolizes not only physical transformation but also ontological and social degradation in German (Kafka, 1915, 1). In Azerbaijani, this phrase is often translated as “giant insect.” Although this translation appears adequate in a literal sense, it does not sufficiently convey the metaphysical dread and existential isolation created by the original, particularly the religious and cultural associations of “Ungeziefer.” This can be considered a case of connotative semantic deviation (Venuti, 1995, 127).

Similarly, the famous expression in James Joyce’s *Ulysses*—“History is a nightmare from which I am trying to awake”—has been translated into Azerbaijani as “Tarix, ayılmağa çalışdığım bir kabusdur” (Joyce, 1922/1992, 78). Here, the multilayered semantics of the word “nightmare”—both individual trauma and the burden of collective historical consciousness—are preserved to some extent. However, Joyce’s irony and tone of subjective denial are weakened. This case may be classified as explicatory transformation (Berman, 1985, 84).

An interesting example from Azerbaijani literature appears in Chingiz Abdullayev’s novel *The Last Verdict*, in the sentence: “He felt the breath of death behind him and knew that this time fate had no desire to joke.” In the Russian translation, this is rendered as “Он почувствовал дыхание смерти за своей спиной и понял — судьбе нынче было не до шуток” (Abdullayev, 2005, 101). Here, the poetic-ironic structure of the original (“no desire to joke”) is replaced by the more standard Russian phrase “не до шуток,” which carries less semantic weight. This represents an example of metaphorical and stylistic deviation (Nida, 1964, 45; Reiss & Vermeer, 1984, 52).

In Anar’s *The Sixth Floor of the Five-Storey Building*, the sentence “If a person’s dreams die, he dies too” has been translated into English as “When a man’s dreams die, he dies too.” This is a successful translation preserving both semantic and syntactic adequacy, as the philosophical depth and stylistic simplicity of the original are fully maintained (Munday, 2001, 74).

The opening line of Leo Tolstoy’s *Anna Karenina*—“Все счастливые семьи похожи друг на

друга, каждая несчастливая семья несчастлива по-своему”—has been translated into many languages as “All happy families are alike; each unhappy family is unhappy in its own way,” demonstrating maximum fidelity to the syntactic and semantic structure of the original (Tolstoy, 1877/2000, 5).

This can be considered an example of adequate translation (Newmark, 1988, 54). The generalized philosophical conclusion presented is adequately rendered into Azerbaijani as: “Bütün xoşbəxt ailələr bir-birinə bənzəyir, hər bədbəxt ailə isə özünəməxsus şəkildə bədbəxtdir.” In this case, neither syntactic nor semantic deviation is observed. Tolstoy’s idea is preserved fully and accurately, which serves as an example of a successful translation strategy.

The analysis conducted on these examples demonstrates that it is impossible to completely avoid semantic deviations in the translation process. Such deviations may arise either from the translator’s aesthetic choices or from code differences existing between languages and cultures. However, a high level of adequacy or the presence of deliberate strategic deviation can help maintain the quality of the translated text. Thus, literary translation continues to maintain its relevance as a creative and analytical activity that considers the multilayered nuances of both language and culture.

Translation activity is more complex and multifaceted than merely transferring words between languages; it is a cornerstone of intercultural dialogue and mutual understanding. The translator, therefore, is not only a language expert but also a mediator acting as a bridge between cultures. In this context, the translator’s responsibilities extend beyond linguistic accuracy to preserving the functional and aesthetic values of the original text while maintaining the integrity of cultural associations and context.

Conclusion

The main objective of the translator is to preserve the communicative function of the original text as much as possible without altering it. This involves not only the correct translation of words but also consideration of the impact, intention, and tone created for the reader. For instance, in literary texts, preserving the author’s style, tone, and emotional load constitutes an essential component of functional adequacy. Each language and culture possesses its own symbols, metaphors, idioms, and contextual nuances. The translator must properly interpret these cultural codes and adapt them to the new linguistic and cultural environment. When direct translation is not possible, the translator may rely on the principle of cultural equivalence and select alternative expressions that preserve the meaning and function of the original text.

Literary translation is one of the most delicate and complex types of translation. It requires the transfer not only of meaning but also of rhythm, poetic structure, and the emotional and aesthetic layers embedded in imagery. The translator’s aesthetic sensitivity and linguistic competence play a crucial role in preserving the artistic value of the text. Translation theorist Lawrence Venuti introduced the concept of the “invisibility of the translator.” According to this thesis,

the most successful translation is one in which the translator remains invisible—meaning that the reader experiences the text as if communicating directly with the original. This idea is considered a key principle for avoiding artificiality or incompleteness in translation. However, Venuti also emphasizes the necessity of translator visibility in certain cases; that is, the translator may need to openly reveal intercultural differences and ideological contexts, intervening as a commentator. This paradoxical situation highlights the importance of the translator functioning both as a passive mediator and an active creator.

Literary translation aims for adequacy as an ideal, yet full and complete realization of this goal is often unattainable. Due to differences in language, culture, and context, semantic deviations become an inevitable part of the translation process. These deviations may sometimes represent unavoidable losses, but they can also serve as productive mechanisms, enriching new interpretations, creative approaches, and intercultural dialogue.

Examples from both Azerbaijani and world literature demonstrate that the higher the translator’s cultural awareness and sensitivity to linguistic and contextual nuances, the greater the level of adequacy achieved. In addition to linguistic competence, the translator’s philosophical and cultural knowledge, ability to analyze and reconstruct the original text, and skill in recreating nuanced meaning are critical factors determining the quality of literary translation. Each translator must carefully consider the layers of meaning, aesthetic elements, and cultural contexts in a text, preserving the spirit of the original while producing a new text suitable for the target culture’s readers.

The findings show that adequacy and semantic deviation in literary translation arise not only from technical linguistic differences but also on deeper levels—lexico-semantic, syntactic, stylistic, and contextual. Typological classifications at these levels demonstrate that translation is not merely a direct linguistic transfer; rather, it is a reconstruction of the text in a new cultural setting while preserving its functional and aesthetic essence.

Based on the results:

a. Lexico-semantic level: Meaning losses or added nuances primarily occur when translating culturally specific words or expressions. These may result from simplifications aimed at clarity or from the translator’s unfamiliarity with the source culture.

b. Syntactic level: Transformations can disrupt the structural rhythm of the original text, potentially diverting from the author’s intent. However, some syntactic changes may be necessary compromises to align with the norms of the target language.

c. Stylistic level: The translator’s greatest challenge is preserving the author’s aesthetic strategy, emotional tone, and writing style. Loss of these components diminishes stylistic adequacy and weakens the poetic power of the text.

d. Contextual level: Failure to accurately render cultural or historical realities may create incomplete or

misleading impressions for the reader, disrupting functional equivalence and obscuring cultural codes embedded in the text.

Thus, this research not only describes the concepts of adequacy and deviation but also systematizes their theoretical, practical, and methodological dimensions. The typological classification based on analyzed examples helps fill conceptual gaps in literary translation theory and supports more precise and purposeful decision-making in translation practice.

Overall, the findings indicate that the translation process is complex, filled with compromises, interpretive choices, and multilayered decisions. Analyzing the forms and levels of adequacy and deviations provides a solid foundation for the scientific study and management of this complexity. This study theoretically and empirically confirms the relativity of adequacy and the inevitability of semantic deviations in literary translation.

In conclusion, adequacy and deviation are complementary and mutually balanced elements in the translation process. By achieving this balance, the translator facilitates effective communication between two cultures and expands the boundaries of literature. Therefore, the success of literary translation depends directly on the translator's professionalism, intercultural awareness, and mastery of the language's poetic possibilities.

References

1. Abdullayev, Ch. (2005). *Sonuncu hökm*. Bakı: Qanun Nəşriyyatı.
2. Anar. (2003). *Beşmərtəbəli evin altıncı mərtəbəsi*. Bakı: Yazıçı.
3. Baker, M. (2011). *In other words: A coursebook on translation* (2nd ed.). Routledge. <https://doi.org/10.4324/9780203837409>
4. Bassnett, S., & Lefevere, A. (Eds.). (1990). *Translation, history and culture*. Routledge.
5. Berman, A. (1985). Translation and the trials of the foreign. In L. Venuti (Ed.), *The translation studies reader* (pp. 284–297). Routledge.
6. Əfəndiyev, R. (2007). *Tərcümə prosesində semantik dəyişmələr*. Bakı: Nurlar.
7. Jakobson, B., & Jakobson, R. (1960). Linguistics and poetic. In T. Sebeok (Ed.), *Style in language* (pp. 350–377). MIT Press.
8. Joyce, J. (1992). *Ulysses* (Original work published 1922). London: Penguin Books.
9. Kafka, F. (1996). *Die Verwandlung*. Frankfurt am Main: Fischer Taschenbuch.
10. Kafka, F. (2008). *Çevrilmə* (Ə. Cahangir, Trans.). Bakı: Şərq-Qərb.
11. Munday, J. (2001). *Introducing translation studies: Theories and applications*. Routledge.
12. Newmark, P. (1988). *A textbook of translation*. Prentice Hall.
13. Nida, E. A. (1964). *Toward a science of translating: With special reference to principles and procedures involved in Bible translating*. Leiden: Brill.
14. Nida, E. A., & Taber, C. R. (2001). *The theory and practice of translation*. Brill.
15. Reiss, K., & Vermeer, H. J. (1984). *Grundlegung einer allgemeinen Translationstheorie [Foundations of a general theory of translation]*. Niemeyer.
16. Saldanha, G., & O'Brien, M. (2016). *Research methodologies in translation studies*. London: Routledge.
17. Scott, C. (2000). *Translating Baudelaire*. University of Exeter Press.
18. Susam-Sarajeva, Ş. (2020). *The politics and poetics of translation in Turkey, 1923–1960*. London: Routledge.
19. Tolstoy, L. (2000). *Anna Karenina* (R. Pevear & L. Volokhonsky, Trans.; Original work published 1877). London: Penguin Classics.
20. Vəliyev, Ə. (2011). *Bədii tərcümədə üslub və ekvivalentlik*. Bakı: Elm və Təhsil.
21. Venuti, L. (2017). *The translator's invisibility: A history of translation* (2nd ed.). London: Routledge.
22. Vermeer, H. J. (1989). Skopos and commission in translational action. In A. Chesterman (Ed.), *Readings in translation theory* (pp. 173–187). Oy Finn Lectura Ab.
23. Williams, J., & Chesterman, A. (2016). *The map: A beginner's guide to doing research in translation studies* (2nd ed.). London: Routledge.

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Ахрамович Володимир Миколайович,
Національний університет «Київський авіаційний інститут»,
Ахрамович Вадим Володимирович,
Національна академія статистики, обліку та аудиту,
Чупрун Сергій Григорович
Державний університет інформаційно-телекомунікаційних технологій
<https://doi.org/10.5281/zenodo.19556950>

УМОВИ НЕВИЗНАЧЕНОСТІ РИЗИКІВ ІНФОРМАЦІЙНИХ СИСТЕМ ТА КІЛЬКІСНА ОЦІНКА ЗБИТКІВ БАНКУ

Akhromovych Volodymyr,
National University "Kyiv Aviation Institute
Akhromovych Vadym,
National Academy of Statistics, Accounting and Audit,
Chuprun Serhii,
State University of Information and Telecommunication Technologies.

CONDITIONS OF UNCERTAINTY OF INFORMATION SYSTEMS RISKS AND QUANTITATIVE ASSESSMENT OF BANK LOSSES

Анотація.

В статті розглянута можливість кількісної оцінки збитків банку з використанням теорії нечітких множин та врахування статистичних даних про ризики їх інформаційних систем.

Abstract

The article considers the possibility of a quantitative assessment of bank losses using fuzzy set theory while taking into account statistical data on risks associated with their information systems.

Ключові слова: збитки банків, ризики, кількісна оцінка, нечіткі множини, приклад.

Keywords: bank losses, risks, quantitative assessment, fuzzy sets, example.

Результати досліджень.**Передумови**

Функції належності відображають, наскільки певний ризик належить до кожної категорії. Наприклад:

$$\text{Високий ризик: } \mu(x) = \begin{cases} 0, & x \leq a \\ \frac{x-a}{b-a}, & a < x < b \\ 1, & x > b \end{cases} \quad (1)$$

де x – оцінка ризику, a , b – межі категорій

Ризик кібератаки можна описати як: ймовірність: середня (0.5), висока (0.7). Вплив: критичний (0.8). Висновок: ризик знаходиться в зоні високої небезпеки (за нечіткими правилами).

Методи трапеції та трикутника широко використовуються в теорії нечітких множин для визначення функцій належності ризиків. Ось приклади:

Метод трикутника

Функція належності у формі трикутника визначається трьома параметрами: (a, b, c) (a, b, c) (a, b, c) , де:

- a : ліва межа (мінімальне значення, де належність = 0),
- b : пік трикутника (максимальна належність = 1),
- c : права межа (значення, де належність знову = 0).

$$\text{Формула: } \mu(x) = \begin{cases} 0, & x \leq a \text{ або } x \geq c \\ \frac{x-a}{b-a}, & a < x \leq b \\ \frac{c-x}{c-b}, & b < x < c \end{cases} \quad (2)$$

Приклад:

Розглянемо ймовірність ризику втрати даних, яка оцінюється за шкалою 0–10. Нехай "середній ризик" має трикутну форму з параметрами (3,5,7) (рис. 1).

$$\text{Якщо } x=4, \mu(4) = \frac{4-3}{5-3} = 0.5$$

$$\text{Якщо } x=6, \mu(6) = \frac{7-6}{7-5} = 0.5$$

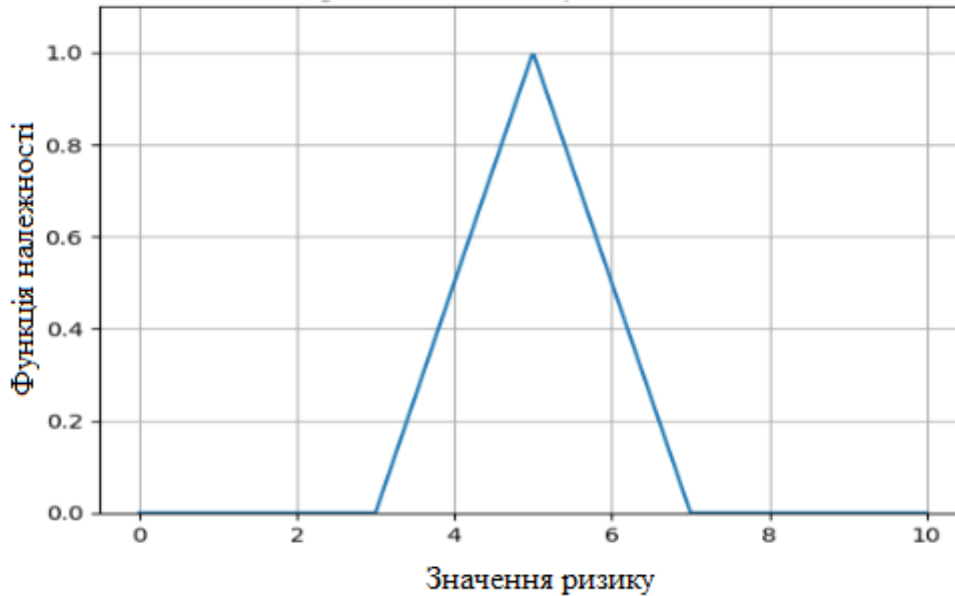


Рис. 1. Трикутна форма середнього ризику

- $x=4$ і $x=6$ належать до "середнього ризику" на 50%.
- $x=5$ - належить на 100%, бо це пік

Метод трапеції

Функція належності у формі трапеції визначається чотирма параметрами: (a,b,c,d) де:

- a: ліва межа (належність = 0),
- b: початок плато (належність починає = 1),
- c: кінець плато (належність = 1),
- d: права межа (належність знову = 0).

$$\text{Формула: } \mu(x) = \begin{cases} 0, & x \leq a \text{ або } x \geq d \\ \frac{x-a}{b-a}, & a < x \leq b \\ 1, & b < x \leq c \\ \frac{d-x}{d-c}, & c < x < d \end{cases} \quad (3)$$

Приклад:

Оцінимо рівень впливу кібератаки на інформаційну систему. «Критичний вплив» описується трапецією з параметрами (6,8,10,12) (рис. 2).

$$\text{Якщо } x=7, \mu(7) = \frac{7-6}{8-6} = 0.5$$

$$\text{Якщо } x=9, \mu(9) = 1, \text{ бо } 8 \leq x \leq 10$$

$$\text{Якщо } x=11, \mu(11) = \frac{12-11}{12-10} = 0.5$$

Таким чином: $x=7$ належить до критичного стану на 50%, $x=11$ належить до критичного стану на 50%, $x=9$ належить до критичного стану на 100%

Комбінація методів

При аналізі ризиків часто комбінують трикутні та трапецієподібні функції. Наприклад:

Ймовірність ризику моделюється трикутником, бо вона має пікову оцінку.

Вплив ризику моделюється трапецією, бо він стабільно високий у певному діапазоні.

Візуалізація

Трикутник використовується, коли потрібно акцентувати на єдиному піковому значенні.

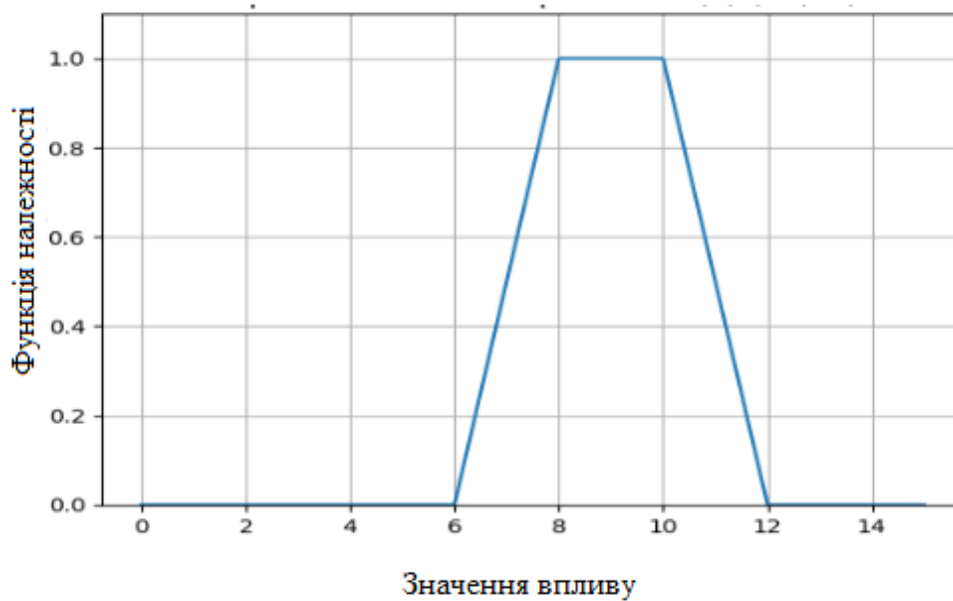


Рис. 2. Рівень впливу кібератаки на інформаційну систему

Трапеція підходить для опису стабільного рівня ризику в межах певного інтервалу.

Ці методи дозволяють адаптивно моделювати ризики з урахуванням нечітких меж і полегшують їх інтерпретацію.

Приклад фазифікації та дефазифікації на основі оцінки ризиків інформаційної системи

Постановка задачі

Оцінимо ризик кібератаки на основі двох змінних:

Ймовірність атаки (P) у відсотках (0–100%).

Вплив атаки (I) за шкалою 0–10.

Вихідна змінна: Рівень ризику (R) за шкалою 0–10. Використовуються три лінгвістичні змінні для кожного параметра:

Ймовірність атаки: низька (Low), середня (Medium), висока (High).

Вплив атаки: незначний (Low), помірний (Medium), критичний (High).

Рівень ризику: низький (Low), середній (Medium), високий (High).

Фазифікація

Фазифікація — це процес перетворення числових даних на нечіткі множини.

Приклад даних:

P=65%, I=7.

Функції належності:

Для ймовірності P: Low: трикутник (0,20,40), $\rightarrow \mu_{Low}(65) = 0$; Medium: трапеція (30,50,70,90),
 $\rightarrow \mu_{Medium}(65) = \frac{90-65}{90-70} = 0.25$; High: трикутник (60,80,100), $\rightarrow \mu_{High}(65) = \frac{65-60}{80-60} = 0.25$

Для впливу I: Low: трикутник (0,2,4), $\rightarrow \mu_{Low}(7) = 0$; Medium: трапеція (3,5,7,9),
 $\rightarrow \mu_{Medium}(7) = 0.5$; High: трикутник (6,8,10), $\rightarrow \mu_{High}(7) = \frac{7-6}{8-6} = 0.5$

Фазифіковані значення:

• P: Medium = 0.25, High = 0.25.

• I: Medium = 0.5, High = 0.5.

Правила нечіткої логіки. На основі фазифікованих значень використовуємо базу правил:

1. Якщо $\rightarrow P_{Low} \text{ і } I_{Low} \rightarrow R_{Low}$

2. Якщо $\rightarrow P_{Medium} \text{ і } I_{Medium} \rightarrow R_{Medium}$

3. Якщо $\rightarrow P_{High} \text{ і } I_{High} \rightarrow R_{High}$

4. Якщо $\rightarrow P_{High} \text{ і } I_{Medium} \rightarrow R_{High}$

... (інші правила)

Значення ступенів належності:

Для правила 2: $\min(0.25, 9.5) = 0.25$

Для правила 4: $\min(0.25, 9.5) = 0.25$

Агрегація

Агрегація об'єднує вихідні ступені належності для різних правил у нечітку множину вихідної змінної

R.

Результат:

$R_{Medium} = 0.25$.

$R_{High} = 0.25$.

Дефазифікація

Дефазифікація перетворює нечітку множину R на конкретне числове значення. Використаємо метод центру ваги (centroid).

$$\text{Формула: } R = \frac{\int x \mu_R(x) dx}{\int \mu_R(x) dx} \quad (4)$$

Розрахунок:

Припустимо, R_{medium} задано трапецією (4,5,6,7). R_{High} - трикутником (6,8,10)

Ваги: $\mu_{Medium}(x) = 0.25$, $\mu_{High}(x) = 0.25$

Обчислення центру ваги дає: $R = \frac{5.5 \cdot 0.25 + 8 \cdot 0.25}{0.25 + 0.25} = 6.75$

Висновок: Рівень ризику становить 6.75 за шкалою 0–10. Це вказує на помірно високий рівень ризику.

Приклад

- Підрахунок можливих збитків за рік банку, коли ймовірність 24 атак вплив атаки критичний, рівень ризику низький (Low); ймовірність 250 атак вплив атаки середній, рівень ризику середній (Medium); ймовірність 3250 атак вплив атаки низький

- Рівень ризику високий (High).

Критичний рівень – збитки від однієї атаки від 1 млн. дол до 500 млн. дол.

Середній рівень - збитки від однієї атаки від 50 тис дол до 500 тис. дол.

Низький рівень. збитки від однієї атаки від 200 дол до 10 тис.. дол.

Процент нейтралізації атак за рахунок захисту 99 відсотків.

- ймовірність атаки (P) у відсотках (0–100%).

- Вплив атаки (I) за шкалою 0–10.

Для розрахунку можливого збитку за рік банку необхідно виконати такі кроки:

Розрахувати збитки для кожного рівня ризику (Low, Medium, High):

Враховується: ймовірність атаки (P). Оскільки кількість атак задана в абсолютних величинах, ймовірність атаки можна вважати 100% для розрахунків загального збитку.

Вплив атаки (I) для визначення діапазону збитків.

- Процент нейтралізації атак (99%), тобто успішно реалізується лише 1% атак.

Розрахункові формули:

Для кожного рівня ризику:

Загальний збиток обчислюється

$$= \text{Кількість атак} \times P \times I \times \text{середній збиток} \times (1 - \text{Процент нейтралізації} / 100)$$

Діапазон збитків:

$$\text{Критичний рівень: середній збиток} = \frac{1000000 + 500000000}{2} = 250500000 \text{ доларів}$$

$$\text{Середній рівень: середній збиток} = \frac{50000 + 500000}{2} = 275000 \text{ доларів}$$

$$\text{Низький рівень: середній збиток} = \frac{200 + 10000}{2} = 5100 \text{ доларів}$$

Підставимо значення:

Критичний рівень:

Кількість атак – 24. Середній збиток – 250 500 000 доларів

Процент нейтралізації 99% (тобто реалізується 1% атак)

Збиток критичний = $24 \times 1 \times 250\,500\,000 \times 0.01 = 60\,120\,000$ доларів

Середній рівень:

Кількість атак – 250. Середній збиток – 275 000 доларів

Процент нейтралізації 99% (тобто реалізується 1% атак)

Збиток середній = $250 \times 1 \times 275\,000 \times 0.01 = 687\,500$ доларів

Низький рівень:

Кількість атак – 3250. Середній збиток – 5 100 доларів

Процент нейтралізації 99% (тобто реалізується 1% атак)

Збиток низький = $3\,250 \times 1 \times 5\,100 \times 0.01 = 165\,750$ доларів

Загальний можливий збиток за рік:

Загальний збиток = Збиток критичний + Збиток середній + Збиток низький = 60 973 250 доларів

Процент нейтралізації атак за рахунок захисту 99 - 99.9 відсотків.

Розрахунок середнього збитку для кожного рівня

Критичний рівень: Збитки від 1 000 000 до 500 000 000 доларів ,

середній = $\frac{1\,000\,000 + 500\,000\,000}{2} = 250\,500\,000$ доларів

Ймовірність атаки P – 24

Вплив I за шкалою 0-10, приймаємо 10

1. Середній рівень: Збитки від 50 000 до 500 000 доларів , середній = 275 000 доларів

Ймовірність атаки P – 250

Вплив I за шкалою 0-10, приймаємо 5

2. Низький рівень: Збитки від 200 до 10 000 доларів , середній = 5 100 доларів

Ймовірність атаки P – 3250

Вплив I за шкалою 0-10, приймаємо 1

• Успішно реалізується 1 % атак, процент нейтралізації атак за рахунок захисту 99%.

• Розрахунок можливого збитку

= $\text{Кількість атак} \times P \times I \times \text{середній збиток} \times (1 - \text{Процент нейтралізації} / 100)$

• Діапазон збитків:

• Критичний рівень: P=24, I=10 середній збиток = 250 500 000 доларів, нейтралізація атак = 99%

• Збиток критичний = $24 \times 1 \times 10 \times 250\,500\,000 \times 0.01 = 600\,120\,000$ доларів

• Середній рівень: середній збиток P=250, I=5 середній збиток = 275 000, нейтралізація атак = 99%

• Збиток середній = $250 \times 1 \times 5 \times 275\,000 \times 0.01 = 3\,437\,500$ доларів

• Низький рівень: середній збиток P=3250, I=1 середній збиток = 5 100, нейтралізація атак = 99,9%

• Збиток низький = $3250 \times 1 \times 1 \times 5\,100 \times 0.001 = 16\,575$ доларів

• Загальний збиток = Збиток критичний + Збиток середній + Збиток низький =

$600\,120\,000 + 3\,437\,500 + 16\,575 = 603\,574\,075$ доларів

Висновкою Можливий збиток банку за рік становить 603 574 075 доларів США, враховуючи 99-99,9% - ефективність захисту.

7. Висновки.

У роботі розроблено підхід до кількісної оцінки збитків банку на основі теорії нечітких множин, що дозволяє враховувати невизначеність та нечіткість параметрів ризику інформаційних систем. Використання лінгвістичних змінних, функцій належності (трикутних і трапецієподібних) та правил нечіткої логіки забезпечує гнучке моделювання ризиків кібератак.

Застосування процедур фазифікації, агрегації та дефазифікації (метод центру ваги) дало змогу перейти від якісних оцінок до конкретних кількісних значень рівня ризику. Запропонований підхід дозволяє здійснювати ранжування ризиків і обґрунтовано приймати управлінські рішення щодо мінімізації можливих збитків.

Проведені розрахунки показали, що навіть при високій ефективності захисту (99–99,9%) сумарні річні збитки можуть досягати значних величин, що підтверджує критичну важливість комплексного управління ризиками інформаційних систем банку. Розроблений програмний інструмент на Python забезпечує практичну реалізацію запропонованого методу та може бути використаний для автоматизації оцінювання збитків.

Список літератури.

1. Водяницька О.В., Соколова Н.В., Сьєрогін С.С. Особливості управління банківськими ризиками. Мукачівський державний університет. Економіка і суспільство. 2018. Випуск 16., с. 700-704.

2. Положення про організацію системи управління ризиками в банках України та банківських групах [Електронний ресурс] : положення, затверджене постановою Правління Національного банку України від 11.06.2018 р. № 64. (редакція від

07.06.2019р.) – Режим доступу <https://zakon.rada.gov.ua/laws/show/v0064500-18>

3. Бобиль В. В. Фінансові ризики банків: теорія та практика управління в умовах кризи: монографія / В. В. Бобиль. – Дніпропетр. нац. ун-т заліз. трансп. ім. акад. В. Лазаряна. – Дніпропетровськ, 2016. – 298 с.

4. Наглядова статистика. Основні показники діяльності банків України. Офіційний сайт НБУ. – [Електронний ресурс]. - Режим доступу:

http://bank.gov.ua/control/uk/publish/article?art_id=36807&cat_id=36798

5. Річний звіт АТ КБ «ПриватБанк» [Електронний ресурс] : на 31 грудня 2018 р. / Офіційний сайт ПАТ КБ «ПриватБанк». – Режим доступу: <https://privatbank.ua/about/finansovaja-otchetnost>

6. Черненко І. І. Удосконалення системи управління операційним ризиком банку / І. І. Черненко, А. В. Олійник // Фінансові аспекти розвитку економіки України: теорія, методологія, практика : Збірник наукових праць молодих вчених та студентів. Том 2 / ред. кол. : Н. А. Хрущ, Р. С. Квасницька, І.

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