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INTERVENTIONAL DIAGNOSTIC METHODS IN MAMMOLOGY

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Abstract. Interventional diagnostic methods in mammology represent a group of minimally invasive procedures performed under imaging guidance to obtain cellular or tissue samples for the morphological verification of breast lesions. The relevance of this topic is обусловлена the high global prevalence of breast cancer and the need for timely and accurate diagnosis to determine the optimal treatment strategy. The aim of this review is to analyze contemporary domestic and international studies focused on interventional diagnostic methods in mammology, as well as to assess their diagnostic effectiveness and safety profile.

Materials and methods included an analysis of publications from scientific databases such as PubMed, eLibrary, and CyberLeninka over recent years. The review incorporates original clinical studies, randomized controlled trials, systematic reviews, and meta-analyses.

The results indicate that core needle biopsy is considered the “gold standard” for preoperative morphological verification of breast lesions due to its high sensitivity and specificity, reaching 95–98%. Vacuum-assisted biopsy allows for the collection of a larger volume of tissue and demonstrates high diagnostic accuracy, particularly in cases involving microcalcifications and high-risk lesions. MRI-guided biopsy is used for lesions visualized exclusively by magnetic resonance imaging and is characterized by high technical success rates and a low false-negative rate. The safety profile of interventional methods is generally favorable. The most common complications include minor bleeding and hematoma formation, whereas severe complications are extremely rare. Pain is typically mild to moderate and depends on the technique used and individual patient characteristics. Thus, interventional diagnostic methods in mammology are highly effective and safe tools that play a key role in the modern diagnosis of breast diseases. At the same time, further standardization of approaches and multicenter studies are required to optimize diagnostic algorithms.

Keywords: mammology, mammography, computed tomography, magnetic resonance imaging, interventional method.

МАММОЛОГИЯДАҒЫ ИНТЕРВЕНЦИЯЛЫҚ ДИАГНОСТИКАЛЫҚ ӘДІСТЕР**Шапамбаев Н.З., Дубовенко Л.Р.***Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті, жоғары медициналық оқу орнынан кейінгі білім беру факультеті (Шымкент, Қазақстан)*

Аңдатпа. Маммологиядағы интервенциялық диагностика әдістері сүт безінің патологиялық өзгерістерін морфологиялық верификациялау үшін жасушалық немесе тіндік материал алу мақсатында көзбен шолып бақылаумен орындалатын аз инвазивті араласулар тобын білдіреді. Тақырыптың өзектілігі сүт безі обырының бүкіл әлемде кең таралуымен және емдеудің оңтайлы тактикасын таңдау үшін уақтылы диагностикалау қажеттілігімен байланысты. Осы шолудың мақсаты маммологиядағы интервенциялық диагностика әдістеріне арналған қазіргі заманғы отандық және шетелдік зерттеулерді талдау, сондай-ақ олардың диагностикалық тиімділігі мен қауіпсіздігін бағалау болып табылады.

Материалдар мен әдістер соңғы жылдары PubMed, eLibrary және CyberLeninka ғылыми дерекқорларында ұсынылған жарияланымдарды талдауды қамтыды. Шолуға бірегей клиникалық зерттеулер, рандомизацияланған бақыланатын зерттеулер, жүйелі шолулар мен метаанализдер енгізілген.

Нәтижелер 95-98% -ға жететін жоғары сезімталдық пен ерекшеліктің арқасында сүт безінің ошақтарын операция алдындағы морфологиялық верификацияның «алтын стандарты» болып табылатынын көрсетті. Вакуум-ассистирленген биопсия тіннің үлкен көлемін алуды қамтамасыз етеді және жоғары диагностикалық дәлдікті көрсетеді, әсіресе микрокальцинаттар мен жоғары қауіп ошақтары болған кезде. МРТ-бағытталатын биопсия тек магниттік-резонанстық томография кезінде ғана визуалданатын ошақтар кезінде қолданылады және жоғары техникалық табыстылықпен және жалған теріс нәтижелердің төмен жиілігімен сипатталады. Интервенциялық әдістердің қауіпсіздік бейіні қолайлы болып табылады. Ең жиі асқынулар шамалы қан кетулер мен гематомалар болып табылады, ал ауыр асқынулар өте сирек кездеседі. Ауырсыну синдромы, әдетте, қалыпты көрінеді және қолданылатын әдістемеге және пациенттің жеке ерекшеліктеріне байланысты болады. Осылайша, маммологиядағы интервенциялық диагностика әдістері сүт безі ауруларын қазіргі заманғы диагностикалауда негізгі рөл атқаратын тиімділігі жоғары және қауіпсіз құралдар болып табылады. Сонымен бірге диагностикалық алгоритмдерді оңтайландыру үшін тәсілдерді одан әрі стандарттау және көп орталықтық зерттеулер жүргізу талап етіледі.

Түйінді сөздер: маммология, маммография, компьютерлік томография, магнитті-резонанстық томография, интервенциялық әдіс.

ИНТЕРВЕНЦИОННЫЕ МЕТОДЫ ДИАГНОСТИКИ В МАММОЛОГИИ**Шапамбаев Н.З., Дубовенко Л.Р.***Международный казахско-турецкий университет имени Ходжа Ахмед Ясави, факультет высшего медицинского послевузовского образования (Шымкент, Казахстан)*

Аннотация. Интервенционные методы диагностики в маммологии представляют собой группу малоинвазивных вмешательств, выполняемых под визуальным контролем с целью получения клеточного или тканевого материала для морфологической верификации патологических изменений молочной железы. Актуальность темы обусловлена высокой распространённостью рака молочной железы во всём мире и необходимостью своевременной диагностики для выбора оптимальной тактики лечения. Целью данного обзора является анализ современных отечественных и зарубежных исследований, посвящённых интервенционным методам диагностики в маммологии, а также оценка их диагностической эффективности и безопасности.

Материалы и методы включали анализ публикаций, представленных в научных базах данных PubMed, eLibrary и CyberLeninka за последние годы. В обзор включены оригинальные клинические исследования, рандомизированные контролируемые исследования, систематические обзоры и метаанализы.

Результаты показали, что кор-биопсия является «золотым стандартом» предоперационной морфологической верификации очагов молочной железы благодаря высокой чувствительности и специфичности, достигающим 95–98%. Вакуум-ассистированная биопсия обеспечивает забор большего объёма ткани и демонстрирует высокую диагностическую точность, особенно при наличии микрокальцинатов и очагов повышенного риска. МРТ-направляемая биопсия применяется при очагах, визуализируемых исключительно при магнитно-резонансной томографии, и характеризуется высокой технической успешностью и низкой частотой ложноотрицательных результатов. Профиль безопасности интервенционных методов является благоприятным. Наиболее частыми осложнениями являются незначительные кровотечения и гематомы, тогда как тяжёлые осложнения встречаются крайне редко. Болевой синдром, как правило, выражен умеренно и зависит от используемой методики и индивидуальных особенностей пациента. Таким образом, интервенционные методы диагностики в маммологии являются высокоэффективными и безопасными инструментами, играющими ключевую роль в современной диагностике заболеваний молочной железы. В то же время требуется дальнейшая стандартизация подходов и проведение многоцентровых исследований для оптимизации диагностических алгоритмов.

Ключевые слова: маммология, маммография, компьютерная томография, магнитно-резонансная томография, интервенционный метод.

Introduction. Interventional diagnostic methods in mammology are minimally invasive, visually guided breast interventions performed to obtain cellular or tissue material for subsequent morphological examination. According to the American College of Radiology (ACR), interventional methods include fine needle aspiration biopsy, core biopsy, vacuum-associated biopsy/excision, as well as stereotactic, ultrasound and MRI guided interventions used on an outpatient basis [5]. The clinical purpose of this type of diagnosis is to describe the characteristics of the tumor and affected lymph nodes for the purpose of subsequent planning of organ—preserving treatment and systemic therapy [21]. The relevance of the topic is determined by the high global burden of breast cancer, where millions of new cases are registered annually, which requires the availability and standardization of interventional methods for timely morphological verification and personalization of treatment [36].

The purpose of the study. Based on current domestic and foreign works, to study interventional diagnostic methods in mammology, their effect on the human body, as well as their effectiveness.

Materials and methods. In the course of this work, we analyzed domestic and foreign publications presented in the scientific databases Elibrary, PubMed and Cyberleninka mainly over the past five years, and also summarized the data obtained by the authors on the topic we are investigating. The inclusion criteria were: publication type — domestic and foreign original clinical trials, randomized controlled trials (RCTs), systematic reviews and meta-analyses published in international peer-reviewed journals. The exclusion criteria were: letters to the editor, brief annotations without data provided, conference materials without the full version of the article, studies not directly related to interventional diagnostic methods and/or mammology.

Results. *Populations and objects of biopsy.*

According to Advani S.S. et al., middle-aged and older women predominate in modern cohorts of patients referred for image-guided breast biopsy. According to the Consortium for Breast Cancer Surveillance. (Breast Cancer Surveillance Consortium, BCSC) among the elderly, the median age is about 73 years [1]. Mammographic density, determined by the Breast Imaging Reporting and Data System (BI-RADS), according to ACR, describes the proportion of fibroglandular tissue and is a key characteristic of the population, influencing both the risk and the choice of a biopsy guidance method [16]. According to a meta-analysis of 42 studies, high density increases the risk of breast cancer by approximately 1.8-4.6 times compared with low density [26]. Dense tissue masks the foci and reduces the sensitivity of mammography, which requires the use of alternative imaging and appropriate biopsy techniques [17]. In these cases, the European Society for Breast Radiology recommends MRI screening [24]. The objects of biopsy depend on the modality: on mammography, these are masses, architectural distortions and microcalcifications, and on MRI, focus, mass and non—mass gain [11]. Stereotactic and tomosynthesis-guided CT biopsy are the methods of choice for microcalcifications and fine mammographic abnormalities without a sonographic correlate [34]. For MR-exclusive lesions, an MRI guided biopsy is the standard [28]. The localization of foci is heterogeneous. So, according to Chen J.H. et al., the highest incidence of malignant lesions is observed in the upper-right quadrant [13]. Microcalcifications predominate in stereotactic biopsy arrays, most objects belong to BI-RADS 4, and the proportion of malignancy is about 30% in individual series [4].

Methods of interventional interventions.

In modern reviews, a core biopsy (CNB) is considered the basic method of morphological verification of breast foci [23]. A core biopsy is usually performed with a 14G needle [12]. According to the clinical recommendations of the European Society of Medical Oncology (ESMO), a CT biopsy provides the determination of immunohistochemical markers ER, PR, HER2 and Ki-67 [21]. The typical volume of sampling during a core biopsy is 3-5 columns of tissue [8]. Vacuum-assisted biopsy (VAB) uses larger calibres - 9-11 G, and allows to take a significantly larger volume of tissue [38]. In a randomized trial, according to Zhang Y. et al., 10G CNB showed higher accuracy and lower frequency of underestimation compared to 14G CNB with a comparable safety profile [20]. In microcalcifications, stereotactic/tomosynthesis-guided VAB with a 9-11 G needle demonstrates a high frequency of calcinate extraction and low underestimation rates [15]. According to Dekker B.M. et al., for a reliable conclusion, the optimal volume of samples at 9G VAB is 6-9 samples [19]. According to Kim H.S. et al., if microcalcifications are visualized on ultrasound, vacuum-assisted biopsy under ultrasound guidance is an effective alternative to stereotactic access [5] (Fig. 1)

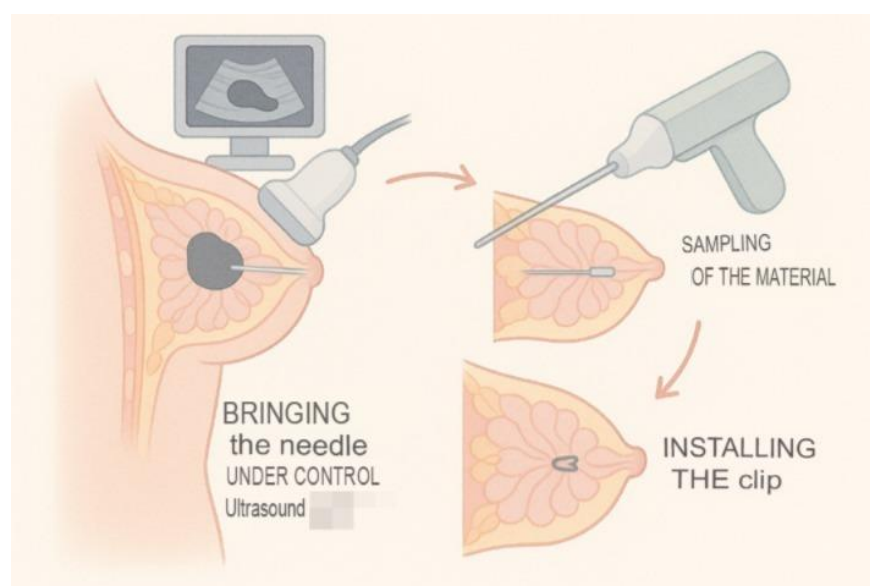


Figure 1. The scheme of material intake.

Diagnostic effectiveness of interventional diagnostic methods.

According to Sauer G. et al., the volume of material obtained during corbiography is high enough. Thus, in large batches, the proportion of insufficient samples did not exceed 0.4%, which directly affects accuracy and reduces the need for repeated interventions [32]. Ziegler-Rodriguez G.J. notes that the overall diagnostic effectiveness of corbiopsy remains at the level of high sensitivity and specificity (about 95-98%), ensuring correct stratification of patients during pre-therapeutic assessment [39]. According to Boba M. et al., False negative results for corbiography are on the order of 2-4%, depending on the technique and concordance of the X-ray-pathomorphological correlation, while the specificity is close to 100% [9]. In the work of Özcan B.B. et al. It is claimed that MR-guided biopsies have a high technical success rate of about 99% and an extremely low false negative percentage of about 0.75% [28]. According to Lu W. et al., vacuum-assisted biopsy demonstrates high sensitivity, about 98% [22].

Special clinical cases.

According to Bick U. et al., microcalcifications without accompanying mass are subject to stereotactic or tomosynthesis-guided vacuum-assisted biopsy in order to maximize calcinate extraction and reduce underestimation of high-risk foci and DCIS [8]. So, Liberman L. Et al. note that directional 11G vacuum-assisted biopsy demonstrates a high frequency of calcinate extraction and diagnostic effectiveness in mammographic abnormalities [20]. If microcalcifications are confidently visualized on ultrasound, a vacuum-assisted biopsy under ultrasound guidance, according to Kim H.S. It is also an effective alternative to stereotactic access [19]. According to Özcan B.B. et al., for foci visible only on MRI, the accepted approach is MR-guided biopsy, characterized by a low proportion of false negative results [28]. If the MR lesion is not contrasted on the day of the intervention, according to the work of Niketa C. et al., short-term MR follow-up with a second biopsy attempt is recommended with reperfusion of the lesion or the appearance of suspicious signs [27].

With regard to B3 pathologies, European interdisciplinary guidelines allow vacuum-assisted excision as an alternative to open biopsy in selected cases, subject to selection criteria and quality control [31]. The guidelines of specialized surgical societies specify that VAB is advisable for individual B3 foci up to 15 mm as an intermediate strategy [6].

Multifocal and multicentric lesions are determined by the presence of several foci in the same quadrant or in different quadrants, respectively, which affects the volume of surgery and requires advanced imaging and careful correlation of biopsy data [25]. These forms are described in the Avera E results. They are more often associated with unfavorable biological characteristics and a worse prognosis compared to unifocal tumors [7]. The sensitivity of standard imaging techniques for detecting multifocality and multicentricity is variable, which justifies the use of MRI and multipath navigation when selecting targets for biopsy [10].

Safety and complications.

Percutaneous breast biopsies are minimally invasive and generally safe procedures. The most common adverse events, according to Bick U. and others - minor bleeding, whereas infectious complications are extremely rare [38]. According to modern studies and reviews, the total frequency of bleeding after biopsies reaches about 10.9%, however, clinically significant hematomas requiring prolonged compression or intervention are significantly less common [37]. In large prospective series, most hematomas are small and clinically insignificant, requiring no specific treatment [14]. Severe vascular complications after vacuum-assisted biopsy are casuistically rare, but cases of massive hematomas successfully treated with endovascular embolization have been described [29]. Pneumo- or hemopneumothorax after percutaneous interventions for foci adjacent to the chest wall are described as isolated cases and are considered extremely rare events [33]. The pain response during most interventions is assessed as mild; An increase in pain intensity is associated with a larger needle gauge, an increase in the number of passages, and preoperative anxiety in the patient [35] (Table 1).

Table 1. Comparative characteristics of pain sensitivity in different types of interventional methods

Method	Assessment of pain sensitivity, according to the visual-analog pain scale	Author
Core biopsy	2.0 – 5.8 - average	Zagouri F. and co-author.[38]
Vacuum-assisted interventions	4.35 ± 1.70 - average	Soon A.E. and co-authors. [1] Zagouri F. And co-author. [2]
Open excision biopsy	9.15 ± 0.74 - high	Soo A.E. and co-authors [1]

Discussion. Despite the widespread use of percutaneous methods, the evidence base remains heterogeneous. Thus, according to Rubio I.T. et al., controversial issues remain regarding the indications of vacuum-assisted excision and surgical excision for B3-lesia [31]. Reporting on complications and risk factors is fragmentary and often does not allow analyzing the impact of patient, focal, and procedural factors [2]. For MR-guided biopsy, meta-analyses confirm high technical success and a low false negative percentage, but according to Özcan B.B. et al., observation strategies after a benign concordant response vary between centers and require unification in the form of risk-based algorithms [28]. Contrast-enhanced mammography as a guidance platform is developing rapidly, but issues of dose loading, diagnostic efficacy, and comparative safety in relation to stereotaxis and tomosynthesis remain research priorities [3]. Modern reviews by the authors emphasize the need for multicenter protocols for corbiography with unification of indications, techniques and endpoints, including economics and acceptability for the patient [18,31,30,39].

Conclusions. Thus, based on the analysis of domestic and foreign publications, it has been established that visually guided interventional methods, primarily corbiography, provide high diagnostic effectiveness with a favorable safety profile and are the standard of pre-therapeutic verification. Vacuum-assisted interventions are justified for microcalcifications and individual B3 pathologies, and routine clip-tag installation and X-ray-pathological correlation increase the accuracy and controllability of subsequent tactics. At the same time, standardization of outcomes, multicenter prospective navigation comparisons and randomized VAE trials against surgical excision, as well as unification of follow-up after benign MR biopsy are required.

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GRNTI 76.29<https://doi.org/10.47526/3080-8715.6486>**MODERN METHODS FOR THE INVESTIGATION OF THYROID DISEASES****Baizhanova K.*, Karim D., Akzhol B., Tashniyazov O., Djumataeva Z.***Khoja Akhmet Yassawi International Kazakh-Turkish University, Faculty of Higher Postgraduate Medical Education (Shymkent, Kazakhstan)***Corresponding author: Baizhanova K., kulay_68@mail.ru*

Abstract. Objective: To review the main methodologies, datasets, and performance indicators of modern research approaches used in the diagnosis of thyroid diseases.

Materials and Methods: A review of the literature published between 2021 and 2026 was conducted to assess the capabilities of contemporary diagnostic methods for thyroid diseases. In all thyroid disorders, a hormonal panel is performed to determine serum levels of thyroid hormones and thyroid-stimulating hormone (TSH). In thyroiditis, autoimmune markers, including antibodies against thyroid peroxidase (TPO), thyroglobulin (Tg), and TSH receptors (TRAb), are measured. Carcinoembryonic antigen (CEA) serves as a biomarker for medullary thyroid carcinoma and carcinoid tumors. Elevated calcitonin levels are characteristic of medullary thyroid carcinoma. Increased thyroglobulin concentrations are observed in destructive thyroid processes and metastatic disease. Fine-needle aspiration biopsy (FNAB) is performed to obtain histological samples from thyroid nodules. When cytological findings are inconclusive, molecular genetic testing is carried out to identify mutations in genes such as BRAF, RAS, and RET/PTC. In addition, in silico approaches are used to identify target genes comprising 19 microRNAs whose expression profiles vary depending on the type of thyroid tumor. Ultrasonography (US), a non-invasive, relatively inexpensive, and real-time imaging technique, is widely used for the early detection and differential diagnosis of thyroid diseases. Ultrasound-guided fine-needle aspiration biopsy is recommended for deeply located thyroid nodules. Since malignant lesions are generally denser and stiffer than benign ones, ultrasound elastography (elastometry) can determine the nature of thyroid nodules with an accuracy of approximately 95–96%, often reducing the need for biopsy. Doppler ultrasonography is used to evaluate the vascularization of the thyroid gland and its nodules. Thyroid scintigraphy employs radioisotope scanning to assess the functional activity of nodular lesions. In recent years, computer-aided diagnostic systems and high-accuracy neural networks based on ultrasound images have been increasingly applied to improve diagnostic accuracy and significantly reduce the time required for clinical decision-making.

Conclusion: Compared with conventional diagnostic approaches, molecular genetic testing, advanced ultrasonographic techniques, computer-aided diagnostic systems, and high-accuracy neural networks provide superior diagnostic accuracy, sensitivity, and specificity in the investigation of thyroid diseases.

Keywords: Thyroid Gland, Molecular Genetic Testing, Computer-Aided Diagnosis, Convolutional Neural Networks

ҚАЛҚАНША БЕЗІ АУРУЛАРЫ ЗЕРТТЕУЛЕРІНІҢ ЗАМАНАУИ ӘДІСТЕРІ

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Қожа Ахмет Ясауи атындағы Халықаралық қазақ-түрік университеті Жоғары медициналық оқу орнынан кейінгі білім беру факультеті (Шымкент, Қазақстан)

Аңдатпа. Жұмыстың мақсаты: қалқанша безі аурулары кезіндегі заманауи зерттеулердің негізгі әдіснамаларына, деректер жиынтықтарына және өнімділік көрсеткіштеріне шолу жасау.

Материалдар мен тәсілдер: 2021-2026 жылдар аралығында жиналған әдебиеттерден қалқанша безі ауруларының заманауи зерттеулерінің мүмкіншіліктерін қарастыру. Барлық қалқанша безі ауруларында гормоналды панель – қан сарысуындағы тиреоидтық гормондары мен тиреотроптық гормонның (ТТГ) деңгейлері анықталады. Тиреодиттерде аутоиммунды маркерлер – тиреоидтық пероксидазаға, тиреоглобулинге және ТТГ рецепторларына қарсы антиденелер титрлері есептеледі. Қалқанша безінің медуллярлық обыры мен карциноидтық ісіктерінің маркері ретінде карциноэмбрионалды антиген табылады. Медуллярлық обырда кальцитонин деңгейі жоғарылайды. Тиреоглобулин деңгейінің жоғарылауы қалқанша безінің деструктивті үрдістерінде, метастаздарында болады. Түйінді құрылымның гистологиясын көру үшін қалқанша безінің жіңішке инемен аспирациялық биопсиясы жасалады. Биопсия қорытындысы нақты нәтиже бермеген жағдайларда молекулалық-генетикалық тестілеуде BRAF, RAS, RET/PTC сияқты мутацияланған гендер ізделінеді. Қалқанша безі ісіктерінің түріне байланысты экспрессия деңгейі өзгертін 19 микроРНК-дан тұратын нысаналы гендерді анықтау үшін *in silico* әдістері қолданылады. Бездің патологияларын ерте анықтау мен ажыратпалы диагностикасы үшін инвазивті емес, салыстырмалы түрде арзан және нақты уақыт режимінде жүргізілетін ультрадыбыстық зерттеуі (УДЗ) кеңінен қолданылады. Қалқанша безінің терең орналасқан түйіндері кезінде УДЗ бақылауымен жіңішке инемен пункциялық биопсия жасалады. Қатерлі ісіктер тығыз және қатты келетіндіктен, биопсия жасамай-ақ түйіннің сипатын 95-96% дәлдікпен анықтауға УДЗ эластографиясы (эластометрия) қолданылады. Бездің және оның ішіндегі түйіндердің қанмен қамтамасыз етілуін (васкуляризациясын) бағалауға доплерография көмек береді. Сцинтиграфия - қалқанша безін радиоизотопты қолдана отырып сканирлеу жасалып, түйінді түзілімдердің қызметтік белсендігін анықтайды. Соңғы жылдары клиникалық жұмыстардың сапасы жақсарту мен диагностикаға кететін уақытты едәуір қысқарту мақсатында ультрадыбыстық кескіндер негізінде қалқанша безі ауруларын анықтау және жіктеу үшін компьютерлік диагностика жүйелер мен жоғары дәлді нейрондық желілер қолданылады.

Қорытынды: қалқанша безі ауруларын зерттеуде дәстүрлі әдістерімен салыстырғанда молекулалық-генетикалық тесттер, заманауи ультрадыбыстық зерттеулер, компьютерлік диагностика жүйелер мен жоғары дәлді нейрондық желілер жоғары дәлдік, сезімталдық және ерекшелік көрсеткіштерін қамтамасыз етеді.

Түйін сөздер: Қалқанша безі, молекулалық-генетикалық тесттер, компьютерлік диагностика жүйелер, жоғары дәлді нейрондық желілер

СОВРЕМЕННЫЕ МЕТОДЫ ИССЛЕДОВАНИЯ ЗАБОЛЕВАНИЙ ЩИТОВИДНОЙ ЖЕЛЕЗЫ

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Аннотация. Цель исследования: провести обзор основных методологических подходов, наборов данных и показателей эффективности современных методов исследования заболеваний щитовидной железы.

Материалы и методы: проведён обзор научной литературы, опубликованной в период 2021–2026 гг., посвящённой современным возможностям исследования заболеваний щитовидной железы. При всех заболеваниях щитовидной железы проводится исследование гормонального профиля с определением уровня тиреоидных гормонов и тиреотропного гормона (ТТГ) в сыворотке крови. При тиреоидитах определяют аутоиммунные маркеры — титры антител к тиреоидной пероксидазе, тиреоглобулину и рецепторам ТТГ. Карциноэмбриональный антиген является маркером медуллярного рака щитовидной железы и карциноидных опухолей. Для медуллярного рака характерно повышение уровня кальцитонина. Повышение концентрации тиреоглобулина наблюдается при деструктивных процессах в щитовидной железе и наличии метастазов. Для гистологической оценки узловых образований выполняется тонкоигольная аспирационная биопсия. При неопределённых результатах цитологического исследования проводится молекулярно-генетическое тестирование с выявлением мутаций генов BRAF, RAS и RET/PTC. Кроме того, методы *in silico* используются для определения генов-мишеней, включающих 19 микроРНК, уровень экспрессии которых изменяется в зависимости от типа опухоли щитовидной железы. Для раннего выявления и дифференциальной диагностики заболеваний щитовидной железы широко применяется ультразвуковое исследование (УЗИ) — неинвазивный, относительно недорогой метод, выполняемый в режиме реального времени. При глубоко расположенных узловых образованиях проводится тонкоигольная пункционная биопсия под контролем УЗИ. Поскольку злокачественные опухоли отличаются большей плотностью и жёсткостью, ультразвуковая эластография (эластометрия) позволяет определить характер узлового образования с точностью 95–96 % без необходимости выполнения биопсии. Допплерография применяется для оценки васкуляризации щитовидной железы и её узлов. Сцинтиграфия основана на радиоизотопном сканировании щитовидной железы и позволяет определить функциональную активность узловых образований. В последние годы для повышения качества клинической диагностики и существенного сокращения времени постановки диагноза всё шире используются системы компьютерной диагностики и высокоточные нейронные сети, основанные на анализе ультразвуковых изображений.

Заключение: по сравнению с традиционными методами исследования молекулярно-генетическое тестирование, современные ультразвуковые технологии, системы компьютерной диагностики и высокоточные нейронные сети обеспечивают более высокие показатели диагностической точности, чувствительности и специфичности при исследовании заболеваний щитовидной железы.

Ключевые слова: Щитовидная железа, молекулярно-генетические тесты, компьютерные диагностические системы, сверхточные нейронные сети

Indroduction. Thyroid diseases are among the most common disorders of the endocrine system. Hypothyroidism affects approximately 3–5% of the global population, while the prevalence of subclinical hypothyroidism reaches up to 10% in some countries. The worldwide prevalence of hyperthyroidism is estimated to range from 0.5% to 2% [1]. According to an international meta-analysis published in 2022, Hashimoto's thyroiditis is diagnosed in approximately 7.5% of the adult population [2]. Based on the GLOBOCAN 2022 database, more than 820,000 new cases of thyroid cancer are diagnosed worldwide each year [3]. In Kazakhstan, the incidence of thyroid cancer increased from 2.9 cases per 100,000 population in 2013 to 5.5 cases per 100,000 population in 2023 [4,5]. These statistics highlight the importance of early diagnosis and continuous endocrinological surveillance of thyroid diseases.

Therefore, the aim of this study is to review the anatomical and physiological characteristics of the thyroid gland and to provide a comprehensive literature review of the principal methodologies, datasets, and performance indicators used in contemporary research on thyroid diseases.

Material and methods. The literature review was conducted using open-access scientific publications published between 2021 and 2026 and retrieved from the PubMed (<https://pubmed.ncbi.nlm.nih.gov/>), Scopus (<https://www.scopus.com/>), and Google Scholar databases. Relevant studies were selected to collect information on contemporary approaches to thyroid disease research, including hormonal panels, autoimmune biomarkers, molecular genetic testing, ultrasonographic techniques, computer-aided diagnostic systems, and high-accuracy convolutional neural networks. Throughout the literature search and review process, the fundamental principles of research ethics were strictly observed..

Results and Discussion. The thyroid gland is the largest endocrine gland in the human body and is located in the anterior region of the neck. It consists of two lateral lobes connected by a narrow isthmus. The gland weighs approximately 10–20 g. Its normal volume is about 18 mL in women and 25 mL in men. Each lobe measures approximately 2.5–4.0 cm in length, 1.5–2.0 cm in width, and 1.0–1.5 cm in thickness. Anatomically, the thyroid gland is closely related to the trachea, esophagus, recurrent laryngeal nerve, common carotid artery, and internal jugular vein. It is covered by the sternocleidomastoid, sternohyoid, and sternothyroid muscles. The gland receives its blood supply primarily from the superior and inferior thyroid arteries. Thyroid blood flow is approximately 5 mL/g/min under normal physiological conditions. During states of increased thyroid activity, blood flow rises markedly, making the gland palpable on physical examination and producing an audible vascular bruit ("thyroid thrill") on auscultation [6].

The thyroid gland is composed predominantly of follicles of various sizes. The follicular lumen is filled with colloid and lined by a single layer of cuboidal epithelial cells known as thyroid follicular cells (thyrocytes). During periods of increased functional activity, these cells become columnar, whereas they flatten when thyroid activity decreases. Numerous microvilli project from the apical surface of the follicular cells into the follicular lumen. Thyrocytes synthesize the glycoprotein thyroglobulin, which is secreted into the follicular lumen by exocytosis. Thyroglobulin has a molecular weight of approximately 660 kDa, and iodine constitutes 0.1–1.0% of its molecular mass. Within the follicular lumen, thyroglobulin serves as the precursor for the synthesis of the thyroid hormones triiodothyronine (T3) and thyroxine (T4). In addition to follicular cells, the thyroid contains parafollicular (C) cells, which synthesize and secrete calcitonin.

Iodine is an essential component required for thyroid hormone synthesis. It is obtained from food and water in the form of inorganic iodide (I^-). According to the recommendations of the World Health Organization (WHO), the daily iodine requirement for adults is 150 μg . When iodine intake falls below 50 $\mu\text{g}/\text{day}$, thyroid hormone synthesis decreases, leading initially to goiter formation and, if prolonged, to hypothyroidism.

Thyroid hormone synthesis begins with the iodination of tyrosine residues within thyroglobulin. To facilitate this process, inorganic iodide (I^-) is actively transported across the basolateral membrane of thyroid follicular cells by the sodium/iodide symporter (NIS), a process driven by the Na^+/K^+ -ATPase. As a result of this active transport mechanism, the concentration of iodide within the thyroid gland becomes approximately 30–40 times higher than that in the bloodstream.

Thyroid peroxidase (TPO), located on the apical membrane of thyroid follicular cells, catalyzes the oxidation of iodide to its active form. This reaction, together with thyroid hormone synthesis, occurs within the follicular colloid. Following oxidation, TPO catalyzes the iodination of tyrosine residues, resulting in the formation of moniodotyrosine (MIT) and diiodotyrosine (DIT). MIT contains one iodine atom, whereas DIT contains two. Subsequently, two DIT molecules couple to form tetraiodothyronine (thyroxine, T4), while the coupling of one MIT and one DIT molecule produces triiodothyronine (T3).

After entering the bloodstream, thyroid hormones (T3 and T4) rapidly bind to their carrier proteins. In serum, only approximately 0.04% of thyroxine (T4) circulates in the free form, whereas 70–75% is bound to thyroxine-binding globulin (TBG), 5–10% to transthyretin (prealbumin), and 15–25% to albumin. Approximately 4% of triiodothyronine (T3) remains unbound in the circulation, while 70–75% is bound to TBG and 25–30% to albumin.

Total thyroxine (TT4) and total triiodothyronine (TT3) include both the free and protein-bound fractions of T4 and T3. However, thyroid function should be assessed primarily by measuring free T3 (FT3) and free T4 (FT4), as the concentrations of protein-bound hormones are influenced by various physiological and pathological conditions, as well as by certain medications. In some cases, increased synthesis or enhanced binding affinity of thyroid hormone-binding proteins results in elevated total T3 and T4 concentrations while free hormone levels remain within the normal range. Conversely, reduced synthesis or decreased binding capacity of these proteins may lower total T3 and T4 concentrations despite normal free hormone levels. Therefore, it is

important to recognize clinical conditions that alter total thyroid hormone concentrations without affecting free hormone levels.

Conditions associated with increased thyroxine-binding globulin (TBG) levels include:

- Hyperestrogenemia (e.g., pregnancy or estrogen therapy);
- Acute infectious hepatitis;
- Hypothyroidism.

Conditions associated with decreased thyroxine-binding globulin (TBG) levels include:

- Androgen therapy;
- Glucocorticoid therapy;
- Malnutrition;
- Nephrotic syndrome;
- Hyperthyroidism;
- Severe systemic illnesses.

The metabolism of thyroid hormones occurs primarily in the liver, kidneys, and other peripheral tissues through the action of deiodinase enzymes. A portion of the released iodine re-enters the extracellular inorganic iodide pool via the bloodstream, while the remainder is taken up again by the thyroid gland for hormone synthesis. The non-iodinated portion of the tyrosine molecule undergoes deamination. Another major metabolic pathway involves the conversion of T4 to T3, followed by conjugation with glucuronic acid in the liver and subsequent excretion in the bile.

Thyroid function is regulated through a negative feedback mechanism. Thyroid-stimulating hormone (TSH), secreted by the anterior pituitary gland, stimulates thyroid function, whereas excessive circulating thyroxine is converted to triiodothyronine (T3) within the pituitary, thereby suppressing the synthesis and secretion of TSH.

TSH is synthesized by thyrotroph cells of the anterior pituitary and is a glycoprotein composed of α - and β -subunits. The α -subunit possesses little biological specificity, whereas the β -subunit is responsible for the biological activity and receptor specificity of TSH. TSH secretion is regulated by thyrotropin-releasing hormone (TRH), which is synthesized in the hypothalamus. TRH is a tripeptide produced primarily by neurons of the paraventricular nucleus and, to a lesser extent, the supraoptic nucleus.

Thyroid follicular cells express specific TSH receptors on their plasma membrane. Binding of TSH to these receptors stimulates virtually all aspects of thyroid function, including the uptake of inorganic iodide, activation of the sodium–potassium ATPase (Na^+/K^+ -ATPase), and increased activity of the sodium/iodide symporter (NIS). TSH also promotes the synthesis of thyroglobulin, thyroid peroxidase (TPO), and lysosomal enzymes within follicular cells. Furthermore, it enhances iodide oxidation, iodination of tyrosine residues within thyroglobulin, and the synthesis of the thyroid hormones triiodothyronine (T3) and thyroxine (T4).

TSH stimulates the endocytosis of colloid vesicles containing thyroglobulin, the hydrolysis of thyroglobulin within lysosomes, and the subsequent release of T3 and T4 into the bloodstream. In addition, TSH promotes the deiodination of monoiodotyrosine (MIT) and diiodotyrosine (DIT), facilitating iodine recycling, while also stimulating thyroid growth and proliferation of thyroid follicular cells. In turn, elevated serum concentrations of T3 and T4 suppress the secretion of both TSH and TRH through a classical negative feedback mechanism. The regulation of TSH and TRH

secretion is primarily mediated by intracellular T3 generated from the deiodination of thyroxine within the pituitary gland and hypothalamus [6].

Thyroid hormones (T3 and T4) exert diverse physiological effects and influence the function of virtually all organs and organ systems. They are essential for normal fetal growth and development, particularly for maturation of the central nervous system. In addition, thyroid hormones play critical roles in regulating the cardiovascular, respiratory, gastrointestinal, endocrine, hematopoietic, and skeletal muscular systems.

The prevalence of thyroid diseases continues to increase worldwide, and these disorders have profound effects on endocrine and metabolic homeostasis.

In recent years, substantial improvements in healthcare services have led to significant advances in laboratory diagnostics of thyroid function. Modern diagnostic technologies are highly accurate, non-invasive, and safe for patients. Contemporary diagnostic approaches enable comprehensive assessment of thyroid morphology, characterization of thyroid nodules, and evaluation of hormonal activity at the molecular level. Moreover, artificial intelligence (AI)-based technologies have significantly enhanced the accuracy of differential diagnosis.

Current diagnostic methods for thyroid diseases can be broadly classified into hormonal and immunological assays, morphological and molecular genetic investigations, as well as instrumental and imaging diagnostic techniques.

I. Hormonal and Immunological Methods

1. Hormonal panel. The hormonal panel includes the measurement of serum thyroid hormones and thyroid-stimulating hormone (TSH) concentrations (Table 1). Before interpreting the laboratory results, it is important to consider that thyroid hormone levels may be influenced by various physiological conditions, pathological states, and medications. Therefore, these factors should always be taken into account to ensure accurate assessment of thyroid function.

Table 1. Normal Serum Concentrations of Free and Protein-Bound Thyroid Hormones (T3 and T4) and Thyroid-Stimulating Hormone (TSH)

Hormone	Value	
	Free	Total
Triiodothyronine (T3)	3,0-8,0 pmol/l (0,2-0,52 pg/ml)	70-132 nmol/l (1,1-2,0 ng/ml)
Thyroxine (T4)	9,0-24,0 pmol/l (0,7-1,9 pg/ml)	64-154,4 nmol/l (5,0-12,0 ng/ml)
Thyroid-Stimulating Hormone (TSH)	0,5-5,0 mIU/L	

In most patients, the use of certain medications may falsely alter thyroid-stimulating hormone (TSH) levels. A list of these medications and their effects is presented in Table 2.

Table 2. Medications Affecting TSH Levels

Increase TSH Secretion Dopamine antagonists: • Metoclopramide • Chlorpromazine • Sulpiride	Suppress TSH Secretion Dopamine agonists: • L-Dopa • Bromocriptine (Parlodel) • Lisuride
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• Haloperidol	• Apomorphine
Clomiphene	Serotonin antagonists:
	• Metergoline
Lithium preparations	Somatostatin (Octreotide)
Carbamazepine	Morphine and its derivatives
Theophylline	Glucocorticoids
	Heparin

During pregnancy, circulating thyroxine-binding globulin (TBG) levels increase in response to elevated estrogen concentrations. As a result, free T4 (FT4) initially decreases, leading to a compensatory increase in thyroid-stimulating hormone (TSH) secretion. Subsequently, a new physiological equilibrium is established. Consequently, total T4 levels increase, whereas free T4 and TSH levels remain within the normal reference range. This highlights the importance of measuring only the free fraction of thyroid hormones during pregnancy.

During the first trimester, the production of human chorionic gonadotropin (hCG) increases markedly. At high concentrations, hCG may exert TSH-like stimulatory effects on the thyroid gland because the two hormones share structural similarities. Consequently, approximately 18–20% of healthy pregnant women have TSH levels below the normal reference range. During the second and third trimesters, TSH levels usually return to the normal range [7].

2. Autoimmune markers (antithyroid antibodies) are essential diagnostic tests for autoimmune thyroiditis. Under normal conditions, antibody titers are:

- Anti-thyroid peroxidase antibodies (Anti-TPO): <1.0 IU/mL
- Anti-thyroglobulin antibodies (Anti-Tg): <1.0 IU/mL

TSH receptor antibodies (TRAb) are autoantibodies directed against receptors that regulate thyroid function. Two types of TRAb have been identified:

- Stimulating antibodies, which increase thyroid hormone production and are elevated in Graves' disease.
- Blocking antibodies, which inhibit thyroid hormone production and are associated with hypothyroidism.

Reference values may vary depending on the assay used. For the diagnosis of autoimmune thyroiditis, simultaneous measurement of Anti-Tg and Anti-TPO antibodies is recommended [8].

3. Tumor markers. Carcinoembryonic antigen (CEA) is used as a tumor marker for medullary thyroid carcinoma as well as other neuroendocrine (carcinoid) tumors.

4. Calcitonin measurement. Serum calcitonin is determined at baseline and again 2.5 minutes after intravenous administration of pentagastrin (0.5 µg/kg). Under normal conditions, serum calcitonin concentrations do not exceed 0.5 ng/mL and remain unchanged following pentagastrin stimulation. In medullary thyroid carcinoma, both elevated basal calcitonin levels and a marked increase after pentagastrin administration are observed.

5. Thyroglobulin (Tg). The normal serum thyroglobulin concentration is <40 ng/mL (40 µg/L). Elevated Tg levels are observed in destructive thyroid disorders, including subacute thyroiditis and silent thyroiditis, and may also occur in hyperthyroidism. In patients with papillary or follicular thyroid carcinoma, serum thyroglobulin measurement after total thyroidectomy is used to detect functioning metastatic disease. A serum thyroglobulin concentration >10 µg/L (10 ng/mL) is considered suggestive of metastatic disease.

II. Morphological and Molecular Genetic Methods

1. Fine-Needle Aspiration Biopsy (FNAB) of the Thyroid Gland. Fine-needle aspiration biopsy (FNAB) is primarily used to evaluate the nature of a thyroid nodule (e.g., to differentiate between a malignant tumor and a cyst). In selected cases, it may also be performed to diagnose autoimmune thyroiditis. Under ultrasound guidance, cells are aspirated from the suspicious nodule and examined microscopically. FNAB remains the only histopathological method capable of definitively confirming thyroid malignancy.

2. Molecular Genetic Testing. Molecular genetic testing is indicated when FNAB cytology yields indeterminate or inconclusive results. In such cases, analysis is performed to detect mutations in genes such as BRAF (B-Raf proto-oncogene), RAS (membrane-associated G proteins), and RET/PTC (chromosomal rearrangements). The development of thyroid cancer is associated with genetic alterations in genes encoding cellular signaling pathways, resulting in disruption of the balance between cell proliferation and apoptosis. Certain mutations are associated with more aggressive tumor behavior, lymph node metastasis, tumor dedifferentiation, and/or reduced responsiveness to radioactive iodine therapy.

The principal genetic alterations implicated in thyroid carcinoma include:

Point mutations: BRAF, RAS, TERT, RET, and TP53.

Gene fusions/rearrangements: RET/PTC, PAX8/PPAR- γ , and NTRK [9–12].

Therefore, molecular genetic analysis of cytological material obtained by preoperative FNAB or thyroid tissue collected after surgery has become widely used in clinical practice.

In recent years, *in silico* approaches have been employed to identify target genes associated with 19 microRNAs whose expression profiles differ according to the histological subtype of thyroid tumors [13]. Based on published studies, nine target genes have been identified as promising biomarkers: MCM2, RASSF2, SPAG9, SSTR2, TP53BP1, INPP4B, CCDC80, GNAS, PLK1.

Additionally, six novel potential biomarkers capable of distinguishing follicular thyroid carcinoma from follicular adenoma have been identified: CDK4, FGFR1, ERBB3, EGR1, MYLK, SRC [14].

The RET proto-oncogene is recognized as a genetic marker for Multiple Endocrine Neoplasia type 2 (MEN2) syndrome and familial medullary thyroid carcinoma.

3. HLA Typing. At present, HLA typing is not routinely used in the clinical diagnosis of thyroid diseases. However, certain HLA alleles are associated with specific thyroid disorders: HLA-B8 and HLA-DR3 are associated with diffuse toxic goiter (Graves' disease) and the atrophic form of autoimmune thyroiditis. HLA-DR5 is associated with the hypertrophic form of autoimmune thyroiditis (Hashimoto's thyroiditis). HLA-Bw35 is considered a genetic marker of subacute thyroiditis (de Quervain thyroiditis), and its presence increases the likelihood of developing this disease by approximately 30-fold.

III. Modern Instrumental and Imaging Diagnostics

1. Thyroid Ultrasonography (Ultrasound, US). Thyroid ultrasonography (US) is a non-invasive, relatively inexpensive, and real-time imaging modality that is widely used for the early detection and characterization of thyroid disorders. The examination allows assessment of the size and volume of the thyroid gland and facilitates the detection of thyroid nodules and cystic lesions.

For non-palpable or deeply located thyroid nodules, ultrasound-guided fine-needle aspiration biopsy (US-guided FNAB) can be performed to obtain cytological specimens for diagnostic evaluation. Table 3 summarizes the ultrasonographic features of various thyroid diseases.

Table 3. **Ultrasonographic Characteristics of Various Thyroid Diseases**

Disease	Ultrasonographic Findings
Toxic adenoma, euthyroid nodular goiter	Hyperechoic nodule with a hypoechoic halo, or hypoechoic nodule; cystic degeneration is common.
Multifocal autonomous thyroid disease	Multiple hyperechoic nodules (their margins are not always well defined), often accompanied by cystic changes; hyperechoic structures are frequently observed.
Diffuse toxic goiter (Graves' disease), autoimmune thyroiditis	Diffuse hypoechogenicity of the thyroid parenchyma.
Subacute thyroiditis	Poorly demarcated hypoechoic areas; diffuse hypoechogenicity is less common.
Malignant tumors (thyroid carcinoma)	Hypoechoic lesions with heterogeneous echotexture and irregular nodules or focal areas.
True thyroid cyst	Anechoic lesion with a regular shape, smooth thin wall, and homogeneous fluid content.
Focal cystic degeneration of nodules	Nodules containing hypoechoic areas with no detectable blood flow on color Doppler ultrasonography.
Colloid nodules	Encapsulated lesions with variable echogenicity.
Thyroid adenomas	Well-defined, round lesions. Echogenicity is usually reduced. Color Doppler imaging typically demonstrates marked peripheral vascularization.
Adenocarcinoma	Poorly defined margins, dense solid lesion with low echogenicity; microcalcifications may be present; capsule is absent.

2. Ultrasound Elastography (Elastometry). Ultrasound elastography (elastometry) is one of the most recent and effective advances in thyroid ultrasonography. Using a specialized transducer, it measures the stiffness and elasticity of thyroid nodules. Because malignant tumors are typically denser and stiffer than benign lesions, elastography can differentiate benign from malignant nodules with an accuracy of 95–96%, thereby reducing the need for unnecessary fine-needle aspiration biopsies.

3. Color Doppler Ultrasonography. Color Doppler ultrasonography is performed during conventional ultrasound examination to assess the vascularity (blood supply) of the thyroid gland

and its nodules. Chaotic intranodular vascularization is considered a sonographic feature suggestive of an increased risk of malignancy.

4. Thyroid Scintigraphy. Thyroid scintigraphy involves radionuclide imaging of the thyroid gland using radioactive iodine (^{125}I or ^{131}I) or technetium-99m sestamibi ($^{99\text{m}}\text{Tc-MIBI}$).

The procedure is used to evaluate the functional activity of thyroid nodules, classifying them as "hot," "warm," or "cold" nodules. It is particularly useful for diagnosing toxic thyroid adenoma, characterized by a hyperfunctioning autonomous ("hot") nodule with suppression of the remaining thyroid tissue.

Normal Radioactive Iodine Uptake (RAIU) Values

Normal thyroid uptake of $^{125}\text{I}/^{131}\text{I}$ is approximately:

- 12–20% at 2 hours
- 30% at 4 hours
- 40% at 6 hours

Conditions Associated with Increased Radioactive Iodine Uptake

- Graves' disease
- Toxic multinodular goiter
- Toxic thyroid adenoma
- TSH-dependent thyrotoxicosis

Conditions Associated with Decreased Radioactive Iodine Uptake

- Subacute thyroiditis
- Painless ("silent") thyroiditis
- Factitious (iatrogenic) thyrotoxicosis
- Hypothyroidism

Radioactive iodine uptake varies according to the body's iodine status. Reduced uptake may occur following: excessive dietary iodine intake (including iodized foods and drinking water), treatment with inorganic iodine, administration of iodinated contrast agents, treatment with amiodarone, or other iodine-containing medications [15].

Because radionuclides have short half-lives and the procedure is relatively expensive, thyroid scintigraphy is performed only for selected clinical indications.

Current Indications for Thyroid Scintigraphy

Thyroid scintigraphy is currently recommended for the following indications:

- To differentiate thyrotoxicosis associated with nodular thyroid disease (solitary nodular, multinodular, or mixed goiter), functionally autonomous thyroid nodules (toxic adenomas), and diffuse toxic goiter (Graves' disease).
- To exclude compensated (subclinical) thyroid autonomy in individuals over 45 years of age with palpable thyroid nodules and/or nodules ≥ 1 cm in diameter.
- Evaluation of a cervical mass suspicious for thyroid malignancy.
- Identification of retrosternal (substernal) thyroid tissue when palpation and ultrasonography are inconclusive.
- Assessment of the effectiveness of thyroidectomy performed for thyroid carcinoma, including postoperative evaluation for residual or recurrent disease.

The clinical significance of thyroid scintigraphy using technetium-99m sestamibi ([^{99m}Tc]Tc-sestamibi, MIBI) has been variable and has somewhat declined with the rapid advancement of thyroid ultrasonography, cytological examination, molecular diagnostics, and positron emission tomography/computed tomography (PET/CT) using ¹⁸F-fluorodeoxyglucose (¹⁸F-FDG). However, recent studies suggest that ^{99m}Tc-sestamibi (MIBI) scintigraphy is regaining clinical importance in selected situations, particularly for the evaluation of thyroid nodules with indeterminate cytology and the diagnosis of iodine-induced thyroid dysfunction [16].

5. Magnetic Resonance Imaging (MRI) and Computed Tomography (CT). Magnetic resonance imaging (MRI) and computed tomography (CT) are valuable imaging modalities for identifying ectopic or atypically located thyroid tissue (e.g., retrosternal or posteriorly displaced thyroid gland), detecting atypically located thyroid nodules, and determining their size and the presence of enlarged cervical lymph nodes. These techniques also facilitate the evaluation of tracheal compression caused by large goiters, local tumor invasion, the extent of thyroid carcinoma, and regional or mediastinal lymph node metastases.

At present, ultrasonography (US) is considered the primary imaging modality for the evaluation of thyroid nodules because it is safe, widely available, and cost-effective. Nevertheless, interpretation of ultrasound findings remains highly dependent on the experience and expertise of the examiner, which may result in interobserver variability and occasionally limited diagnostic accuracy.

In recent years, artificial intelligence (AI) has fundamentally transformed medical image analysis by enabling automated feature extraction, lesion classification, and clinical decision support. The application of AI—particularly machine learning (ML) and deep learning (DL) algorithms - to thyroid disease diagnosis has substantially improved diagnostic performance [17,18].

AI-based approaches provide high diagnostic accuracy, reduced interobserver variability, and more consistent clinical decision-making across diverse clinical settings. Accurate diagnosis is essential not only for identifying the specific type of thyroid disease but also for selecting the most appropriate individualized treatment strategy. Early diagnosis and timely intervention improve clinical outcomes and significantly enhance patients' quality of life.

Machine learning algorithms play an important role in the characterization of thyroid lesions, particularly in the classification of benign and malignant thyroid nodules detected by ultrasonography. Early machine learning methods - including Support Vector Machines (SVMs), k-Nearest Neighbors (k-NN), and Decision Trees - were combined with manually engineered image features such as gray-level co-occurrence matrix (GLCM) texture descriptors, wavelet transforms, and histogram-based features, yielding satisfactory diagnostic performance.

The introduction of deep learning, particularly Convolutional Neural Networks (CNNs), has significantly improved diagnostic accuracy, sensitivity, and specificity in numerous studies. By automatically learning hierarchical image features directly from data, CNN-based models outperform traditional handcrafted feature-based approaches and frequently achieve diagnostic accuracies exceeding 95%.

Furthermore, hybrid and ensemble models that combine CNN architectures with conventional classifiers (e.g., Random Forest or SVM) or incorporate attention mechanisms have

demonstrated further improvements in model robustness, interpretability, and diagnostic performance [19–21].

Despite ongoing challenges related to dataset heterogeneity, generalizability, and model interpretability, machine learning–based diagnostic systems are increasingly regarded as scalable, non-invasive, and reproducible clinical decision-support tools that assist clinicians in the early and accurate diagnosis of thyroid diseases.

Conclusion. Compared with conventional diagnostic approaches, molecular genetic testing, advanced ultrasonographic techniques, computer-aided diagnostic systems, and high-performance neural network–based artificial intelligence models have demonstrated superior diagnostic performance in the evaluation of thyroid diseases, particularly thyroid nodules. These modern approaches provide higher diagnostic accuracy, sensitivity, and specificity, resulting in more reliable disease detection, improved diagnostic confidence, and better support for clinical decision-making.

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MODERN APPROACHES TO THE TREATMENT OF CHRONIC SENSORINEURAL HEARING LOSS: THE ROLE OF "AUDIOTONE" AND "TONSILLOR" DEVICES

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Abstract. Background and Objective: Chronic sensorineural hearing loss (CSNHL) remains one of the most significant unresolved challenges in modern otolaryngology. This study evaluates the efficacy and safety of combined physiotherapy devices "Audiotone" and "Tonsillor" in the treatment of CSNHL of vascular etiology.

Methods: A prospective clinical trial was conducted involving 62 patients (age 40-53 years) with CSNHL of vascular origin. Patients underwent comprehensive treatment using "Audiotone" and "Tonsillor" devices combined with conventional pharmacotherapy. Pure-tone audiometry was performed before treatment, immediately after treatment, and at 1-month follow-up.

Results: Subjective improvement in hearing and reduction of tinnitus occurred by days 5-6 of treatment. Statistically significant hearing improvement was demonstrated at frequencies 3, 4, 6, and 8 kHz (improvement of 14-17 dB) in patients with CSNHL grades I and II. Process stabilization was achieved in grade III CSNHL patients. Tinnitus intensity reduction was reported in 85.5% (53/62) of patients. Complete audiological recovery was not achieved in any group, but combined treatment demonstrated superior outcomes compared to pharmacotherapy alone.

The combined use of "Audiotone" and "Tonsillor" devices represents a safe, non-invasive, and effective adjunctive therapy for CSNHL of vascular etiology. This approach acts through multiple pathophysiological mechanisms: improvement of microcirculation, enhanced drug delivery, anti-inflammatory effects, and restoration of auditory function. Treatment outcomes were most favorable in early-stage disease with shorter symptom duration.

Keywords: chronic sensorineural hearing loss, Audiotone, Tonsillor, Cavinton, low-frequency ultrasound, magnetic therapy, laser therapy

СОЗЫЛМАЛЫ СЕНСОНЕВРАЛДЫ ЕСТУ ҚАБІЛЕТІНІҢ ЖОҒАЛУЫН ЕМДЕУДІҢ ЗАМАНАУИ ТӘСІЛДЕРІ: «АУДИОТОН» ЖӘНЕ «ТОНЗИЛЛОР» ҚҰРЫЛҒЫЛАРЫНЫҢ РӨЛІ

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Аңдатпа. Созылмалы сенсонеуралды есту қабілетінің жоғалуы (ССНЕҚЖ) қазіргі оториноларингологиядағы өзекті медициналық және әлеуметтік мәселелердің бірі болып табылады. Аурудың патогенезінің күрделілігі мен емдеу нәтижелерінің шектеулілігі тиімді терапиялық тәсілдерді іздестіруді талап етеді. Осыған байланысты физиотерапиялық технологияларды кешенді емдеу құрамында қолданудың клиникалық тиімділігін бағалау ерекше қызығушылық тудырады. Зерттеудің мақсаты – тамырлы этиологиялы созылмалы сенсонеуралды есту қабілетінің жоғалуын емдеуде «Аудиотон» және «Тонзиллор» физиотерапиялық құрылғыларын кешенді қолданудың тиімділігі мен қауіпсіздігін бағалау.

Зерттеуге жасы 40–53 жас аралығындағы тамырлы генезді созылмалы сенсонеуралды есту қабілетінің жоғалуы бар 62 пациент енгізілді. Перспективалық клиникалық зерттеу аясында барлық науқастарға стандартты фармакотерапиямен қатар «Аудиотон» және «Тонзиллор» құрылғыларын қолдану арқылы кешенді ем жүргізілді. Есту функциясының динамикасы таза тондық аудиометрия әдісімен ем басталғанға дейін, емдеу аяқталғаннан кейін және 1 айлық бақылау кезеңінде бағаланды.

Нәтижелер. Емдеудің 5–6-күнінен бастап пациенттердің басым бөлігінде естудің субъективті жақсаруы және құлақтағы шудың қарқындылығының төмендеуі байқалды. I және II дәрежелі созылмалы сенсонеуралды есту қабілетінің жоғалуы бар науқастарда 3, 4, 6 және 8 кГц жиіліктерде есту табалдырығының статистикалық тұрғыдан маңызды төмендеуі анықталды, жақсару көрсеткіші орта есеппен 14–17 дБ құрады ($p < 0,05$). III дәрежелі ССНЕҚЖ бар пациенттерде аурудың үдемеуіне және клиникалық жағдайдың тұрақтануына қол жеткізілді. Құлақтағы шудың қарқындылығы 62 пациенттің 53-інде (85,5%) төмендеді. Толық аудиологиялық қалпына келу жағдайлары тіркелмегенімен, кешенді емдеу әдісі дәстүрлі фармакотерапиямен салыстырғанда жоғары клиникалық тиімділікті көрсетті.

Қорытынды. «Аудиотон» және «Тонзиллор» физиотерапиялық құрылғыларын кешенді қолдану тамырлы этиологиялы созылмалы сенсонеуралды есту қабілетінің жоғалуын емдеудің қауіпсіз, инвазивті емес және клиникалық тұрғыдан тиімді қосымша әдісі болып

табылады. Бұл емдеу тәсілі микроциркуляцияны жақсарту, дәрілік заттардың тіндерге жеткізілуін күшейту, қабынуға қарсы әсер ету және есту анализаторының функционалдық жағдайын қалпына келтіру сияқты бірнеше патогенетикалық механизмдер арқылы жүзеге асады. Ең жоғары терапиялық тиімділік аурудың ерте сатыларында және клиникалық симптомдардың ұзақтығы қысқа болған жағдайда байқалды. Алынған нәтижелер созылмалы сенсоневралды есту қабілетінің жоғалуын кешенді емдеу алгоритміне аталған физиотерапиялық әдістерді енгізудің клиникалық орындылығын көрсетеді.

Түйін сөздер: созылмалы сенсоневралды есту қабілетінің жоғалуы, Аудиотон, Тонзиллор, кавинтон, төмен жиілікті ультрадыбыс, магниттік терапия, лазерлік терапия

СОВРЕМЕННЫЕ ПОДХОДЫ К ЛЕЧЕНИЮ ХРОНИЧЕСКОЙ СЕНСОНЕВРАЛЬНОЙ ТУГОУХОСТИ: РОЛЬ АППАРАТОВ «АУДИОТОН» И «ТОНЗИЛЛОР»

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Аннотация. Хроническая сенсоневральная тугоухость (ХСНТ) остается одной из наиболее значимых нерешенных проблем современной отоларингологии. В данном исследовании оценивается эффективность и безопасность комбинированных физиотерапевтических устройств «Аудиотоне» и «Тонзиллор» при лечении ХСНТ сосудистой этиологии.

Методы: Было проведено проспективное клиническое исследование с участием 62 пациентов (возраст 40-53 года) с ХСНТ сосудистого происхождения. Пациенты прошли комплексное лечение с использованием устройств «Аудиотоне» и «Тонзиллор» в сочетании с традиционной фармакотерапией. Аудиометрия порогов слуха проводилась до лечения, сразу после лечения и через 1 месяц после лечения.

Результаты: Субъективное улучшение слуха и уменьшение шума в ушах наблюдались на 5-6 день лечения. Статистически значимое улучшение слуха было продемонстрировано на частотах 3, 4, 6 и 8 кГц (улучшение на 14-17 дБ) у пациентов с ХСНТ I и II степени. Стабилизация процесса была достигнута у пациентов с ХСНТ III степени. Снижение интенсивности шума в ушах было отмечено у 85,5% (53/62) пациентов. Полного

восстановления слуха не было достигнуто ни в одной группе, но комбинированное лечение продемонстрировало лучшие результаты по сравнению с одной только фармакотерапией.

Комбинированное использование устройств «Аудиотон» и «Тонзиллор» представляет собой безопасную, неинвазивную и эффективную вспомогательную терапию при ХСНТ сосудистой этиологии. Этот подход действует посредством множественных патофизиологических механизмов: улучшение микроциркуляции, улучшенная доставка лекарственных средств, противовоспалительное действие и восстановление слуховой функции. Результаты лечения были наиболее благоприятными на ранних стадиях заболевания с более короткой продолжительностью симптомов.

Ключевые слова: Хроническая сенсоневральная тугоухость, «Аудиотон», «Тонзиллор», Кавинтон, низкочастотный ультразвук, магнитотерапия, лазерная терапия

Introduction. Chronic sensorineural hearing loss (CSNHL) represents one of the most prevalent diseases and urgent problems in otolaryngology. According to epidemiological data, 1-6% of the global population suffers from significant hearing impairment, with CSNHL accounting for 74% of all hearing loss cases [1]. This condition constitutes an important medical and social problem, particularly affecting economically active individuals aged 30-50 years. CSNHL is a polyetiological disease characterized by progressive damage to the cochlear receptor apparatus, auditory nerve, and central auditory pathways [2, 3]. The progressive nature of the condition leads to severe communication restrictions, reduced professional activity, and significant psychological alterations [4].

Recent attention has focused on vascular, metabolic, and neurodegenerative mechanisms in CSNHL pathogenesis. Microcirculatory disturbances of the inner ear, leading to hypoxia and damage to neurosensory cells of the organ of Corti, play a crucial role [5, 6]. The internal auditory artery, a terminal branch of the vertebrobasilar system, lacks collateral circulation, making the inner ear particularly vulnerable to ischemic insult even during brief vascular disturbances [7, 8].

Recent advances in understanding the blood-labyrinth barrier have revealed its critical role in inner ear homeostasis. Dysfunction of this barrier leads to microcirculatory changes, oxidative stress, and neurosensory damage [8]. Pericytes-vascular wall cells regulating capillary blood flow and vascular permeability-have emerged as important targets for therapeutic intervention. Pericyte dysfunction can reduce cochlear capillary perfusion, leading to progressive hearing deterioration [9].

Traditional CSNHL therapy employs vascular, nootropic, and metabolic agents; however, treatment efficacy remains limited. This has prompted development of physiotherapeutic methods targeting local blood flow enhancement, inflammation reduction, and improved drug delivery to inner ear tissues. The "Tonsillor" and "Audiotone" devices (NPP Metromed, Omsk, Russia) represent innovative physiotherapy instruments combining low-frequency ultrasound (LFUS), electrical microcurrent stimulation, magnetic therapy, and infrared laser therapy [11, 12]. These devices enable simultaneous modulation of multiple pathophysiological mechanisms [1].

Objective. To assess the efficacy of the physiotherapy complex "Audiotone" and "Tonsillor" in the treatment of chronic sensorineural hearing loss of vascular etiology.

Material and Methods

1 Study Design. A prospective comparative clinical trial was conducted at the Department of Otolaryngology, Course of Otolaryngology, Department of Special Surgical Disciplines at Khoja Akhmet Yassawi International Kazakh-Turkish University, Shymkent, Kazakhstan. The study was performed in accordance with the ethical principles of the Declaration of Helsinki (1964, revised 2000). Informed consent was obtained from all participants.

2 Study Participants. Sixty-two patients (28 men, 34 women) aged 40-53 years (mean age 47 years) with CSNHL of vascular etiology were enrolled. Inclusion criteria: clinically confirmed CSNHL, disease duration exceeding 3 months, stable disease course, and informed written consent. Exclusion criteria: acute inflammatory ENT diseases, neoplastic processes, decompensated somatic conditions, and pregnancy. Based on pure-tone audiometric results, patients were classified as: grade I (n=15, 24.2%), grade II (n=33, 53.2%), or grade III (n=14, 22.6%).

3 Assessment Methods. All patients underwent comprehensive evaluation: otorhinolaryngologic examination, pure-tone threshold audiometry, high-resolution computed tomography/magnetic resonance imaging of temporal bones (when indicated), complete blood count, urinalysis, electrocardiography, chest radiography, and consultations with neurology and internal medicine specialists. Treatment efficacy was evaluated based on: (1) changes in auditory thresholds (dB) at key frequencies; (2) subjective hearing assessment; (3) presence/reduction of tinnitus; (4) audiometric assessment at baseline, post-treatment, and 1-month follow-up.

4 Treatment Protocol. All patients received comprehensive treatment employing "Audiotone" and "Tonsillor" devices over 10 consecutive days. "Audiotone" treatment included: (1) Magnetic therapy to the inner ear: endaural magnetic probe application, 20 minutes daily for 10 days; (2) Electrophoresis: endaural electrode placement with Cavinton-soaked gauze, electrical nerve-receptor stimulation of cochlear apparatus with adjustable frequency and amplitude, 10 minutes daily for 10 days; (3) Infrared laser therapy: infrared laser beam directed at the promontory with penetration into middle and inner ear structures, 15 minutes daily for 10 days.

"Tonsillor" low-frequency ultrasound treatment: 4.0-5.0 mL Cavinton solution introduced into external auditory canal with endaural waveguide applying ultrasonic impregnation (frequency 26.5 kHz, amplitude 10-40 μ m, pulsed mode, 20-30 seconds daily for 10 days).

Following physiotherapy, nasal decongestant (0.05% oxymetazoline) was applied, and Politzerization and pneumomassage of tympanic membranes were performed.

Results

1 Clinical Outcomes. Subjective improvement in hearing, tinnitus reduction, and general symptom improvement were reported by patients on days 5-6 of treatment. Pure-tone audiometric analysis demonstrated statistically significant hearing threshold improvement at frequencies 3, 4, 6, and 8 kHz (14-17 dB improvement) in patients with CSNHL grades I and II. In grade III CSNHL patients, process stabilization was achieved. Tinnitus intensity reduction was reported by 85.5% (53/62) of patients. Most favorable treatment outcomes were observed in early-stage disease with shorter symptom duration.

2 Proposed Mechanisms of Clinical Benefit. The clinical efficacy observed in this series likely results from the combined effects of multiple therapeutic modalities:

Magnetic Therapy: Water molecules in blood and lymph become magnetized, enhancing cellular metabolism, promoting restoration processes, improving blood circulation, and normalizing vascular caliber and tone.

Electrophoresis with Cavinton: Cavinton ionizes and penetrates skin layers of the external auditory canal and middle ear structures (tympanic membrane, ossicular chain, tympanic mucosa) to reach the cochlear nerve-receptor apparatus, achieving high local concentrations with sustained bioavailability. This stabilizes microcirculation and enhances drug tissue penetration.

Infrared Laser Therapy: Produces biochemical changes at subcellular, cellular, tissue, and organism levels. Improves microcirculation, stimulates neovascularization, enhances blood flow, activates transcapillary transport, and reduces interstitial and intracellular edema.

Low-Frequency Ultrasound: Produces micromassage and loosening of external auditory canal skin, facilitating deep Cavinton penetration and enhancing microcirculation. Ultrasound induces cavitation, thermal, and physicochemical effects, increasing Cavinton concentration in cellular and extracellular compartments.

Discussion. This study demonstrates that incorporation of "Audiotone" and "Tonsillor" devices into comprehensive CSNHL treatment promotes auditory function improvement, reduces subjective tinnitus, and enhances quality of life. The most pronounced therapeutic effects were observed in patients with initial and moderately severe disease stages and relatively short symptom duration. Most favorable outcomes occurred in grade I-II CSNHL patients, while grade III patients demonstrated disease stabilization without further deterioration.

The positive effects of "Audiotone" are attributable to improved microcirculation, stimulation of metabolic processes in the inner ear, and neuroprotection of auditory analyzer structures. Low-frequency ultrasound reduces ischemic cochlear changes, improves tissue nutrition, and facilitates functional recovery of inner ear receptor apparatus. The non-invasive nature, excellent tolerability, and potential for repeated treatment courses support consideration of this approach as a pathogenetically justified, promising therapeutic modality.

Study limitations include single-center design and relatively small sample size. Multicenter randomized controlled trials with larger patient populations and extended follow-up periods are warranted to confirm these findings and elucidate long-term recurrence patterns.

Conclusion. The combined use of "Audiotone" and "Tonsillor" physiotherapy devices represents a modern, highly effective, safe, and patient-friendly adjunctive treatment for chronic sensorineural hearing loss of vascular etiology. This multimodal approach acts through complementary mechanisms targeting vascular, inflammatory, and neurotropic disease pathways. Treatment demonstrates excellent tolerability, non-invasive delivery, and capacity for repeated therapeutic courses. In early-stage disease with shorter symptom duration, outcomes are most favorable. This approach offers a valuable alternative or complement to conventional CSNHL management strategies.

Declarations

Ethical Approval. All procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki (1964, revised 2000). Institutional ethical approval was obtained prior to study initiation. Informed written consent was secured from all participating patients.

Informed Consent. All patients provided written informed consent prior to enrollment in the study.

Conflicts of Interest. The authors declare no conflicts of interest relevant to this manuscript.

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Data Availability. The datasets analyzed in this study are available from the corresponding author upon reasonable request, subject to institutional ethics review board approval and patient confidentiality requirements.

Author Contributions. S.A.O. designed and conducted the clinical trial, collected and analyzed data, and prepared the manuscript. M.A.O. participated in patient recruitment, data collection, and manuscript preparation. A.A.Y. contributed to study design and critical manuscript revision. A.Z.I., O.A.P., A.K.A., R.S.F., A.N.N., E.K.T., and G.E.A. participated in patient care and data collection. All authors reviewed and approved the final manuscript.

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METAPHYLAXIS OF NEPHROLITHIASIS: A PATHOGENETIC APPROACH USING MEDICINAL PLANTS AND LOCAL REMEDIES FROM SOUTHERN KAZAKHSTAN

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Abstract. Recurrent nephrolithiasis remains one of the most challenging problems in contemporary urology. This study presents a comprehensive, pathogenesis-based approach to metaphylaxis (prevention of recurrent stone formation) using medicinal plants, traditional beverages, and acidic mineral waters endemic to Southern Kazakhstan. Over a 12-year period, 500 patients with various forms of urolithiasis were treated using protocols developed based on the proteolysis-ion theory of stone formation. The study evaluated the effects of galenic preparations from camel thorn (*Alhagi pseudalhagi*), Turkestan bedstraw (*Galium turkestanicum*), kumiss (fermented mare's milk), and acidic mineral waters (Chelkar and Zhosalin springs) on urine pH, proteolytic activity, and diuresis—the primary risk factors for urolithiasis. Treatment regimens were differentiated according to stone type: urate, calcium oxalate, and phosphoric acid nephrolithiasis. Results demonstrated a reduction in recurrence rates to 13% in the treatment group versus 62.7% in the control group, with a 1.5-fold reduction in disability rates. This evidence-based approach provides practical therapeutic recommendations suitable for implementation in resource-limited settings and offers a model for integrating traditional medicine with modern urological practice.

Keywords: nephrolithiasis, metaphylaxis, proteolysis, urine pH, urate stones, calcium oxalate lithiasis, phosphoric acid nephrolithiasis, phytotherapy, medicinal plants, kumiss, mineral waters, enzyme therapy, diuresis

НЕФРОЛИТИАЗДЫҢ МЕТАФИЛАКСИСІ: ОҢТҮСТІК ҚАЗАҚСТАННАН АЛЫНҒАН ДӘРІЛІК ӨСІМДІКТЕР МЕН ЖЕРГІЛІКТІ ЕМДЕУ ҚҰРАЛДАРЫН ҚОЛДАНУ БОЙЫНША ПАТОГЕНЕТИКАЛЫҚ КӨЗҚАРАС

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Аннотация. Қайталанатын нефролитиаз қазіргі заманғы урологиядағы ең күрделі мәселелердің бірі болып қала береді. Бұл зерттеуде Оңтүстік Қазақстанға тән дәрілік өсімдіктерді, дәстүрлі сусындарды және қышқыл минералды суларды қолдана отырып, метафилаксияға (қайталанатын тас түзілуінің алдын алу) кешенді, патогенезге негізделген тәсіл ұсынылған. 12 жылдық кезеңде уролитиаздың әртүрлі түрлерімен ауыратын 500 науқас тас түзілуінің протеолиз-иондық теориясына негізделген хаттамаларды қолдана отырып емделді. Зерттеуде түйе тікенегінен (*Alhagi pseudalhagi*), Түркістан төсек сабанынан (*Galium turkestanicum*), қымыздан (ашытылған бие сүтінен) және қышқыл минералды сулардан (Челкар және Жосалин бұлақтары) алынған галендік препараттардың зәрдің рН-на, протеолитикалық белсенділігіне және диурезге - уролитиаздың негізгі қауіп факторларына әсерін бағалады. Емдеу режимдері тас түріне қарай сараланды: урат, кальций оксалат және фосфор қышқылы нефролитиазы. Нәтижелер емдеу тобында қайталану деңгейінің 13%-ға дейін төмендегенін, ал бақылау тобында бұл көрсеткіш 62,7%-ға жеткенін, ал мүгедектік деңгейінің 1,5 есе төмендегенін көрсетті. Бұл дәлелді тәсіл ресурстары шектеулі жағдайларда қолдануға жарамды практикалық терапиялық ұсыныстар береді және дәстүрлі медицинаны заманауи урологиялық тәжірибемен біріктіру моделін ұсынады.

Түйін сөздер: нефролитиаз, метафилаксия, протеолиз, зәрдің рН деңгейі, урат тастары, кальций оксалат литииазы, фосфор қышқылы нефролитиазы, фитотерапия, дәрілік өсімдіктер, қымыз, минералды сулар, ферменттік терапия, диурез

МЕТАФИЛАКТИКА НЕФРОЛИТИАЗА: ПАТОГЕНЕТИЧЕСКИЙ ПОДХОД С ИСПОЛЬЗОВАНИЕМ ЛЕКАРСТВЕННЫХ РАСТЕНИЙ И МЕСТНЫХ СРЕДСТВ ЮЖНОГО КАЗАХСТАНА

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Аннотация. Рецидивирующий нефролитиаз остается одной из наиболее сложных проблем современной урологии. В данном исследовании представлен комплексный, основанный на патогенезе подход к метафилактике (профилактике рецидивирующего образования камней) с использованием лекарственных растений, традиционных напитков и кислых минеральных вод, эндемичных для Южного Казахстана. В течение 12 лет 500 пациентов с различными формами уролитиаза были пролечены с использованием протоколов, разработанных на основе протеолизно-ионной теории образования камней. В исследовании оценивалось влияние галеновых препаратов из верблюжьей колючки (*Alhagi pseudalhagi*), туркестанской подмаренницы (*Galium turkestanicum*), кумыса (ферментированного кобыльего молока) и кислых минеральных вод (источники Челкар и Жосалин) на pH мочи, протеолитическую активность и диурез — основные факторы риска мочекаменной болезни. Схемы лечения различались в зависимости от типа камней: уратный, оксалат кальция и фосфорнокислотный нефролитиаз. Результаты показали снижение частоты рецидивов до 13% в группе лечения по сравнению с 62,7% в контрольной группе, а также 1,5-кратное снижение уровня инвалидности. Этот научно обоснованный подход предоставляет практические терапевтические рекомендации, подходящие для внедрения в условиях ограниченных ресурсов, и предлагает модель интеграции традиционной медицины с современной урологической практикой.

Ключевые слова: нефролитиаз, метафилактика, протеолиз, pH мочи, уратные камни, оксалат кальция, фосфорнокислотный нефролитиаз, фитотерапия, лекарственные растения, кумыс, минеральные воды, ферментная терапия, диурез

Introduction. Nephrolithiasis (kidney stone disease) is one of the most prevalent urological disorders worldwide, affecting approximately 20–25% of the general population and accounting for up to 50% of urological admissions in some regions [1, 2, 3]. The disease is characterized by the formation of crystalline concretions in the urinary tract, leading to obstructive uropathy, calculous pyelonephritis, and ultimately chronic kidney disease if untreated [1, 3]. While the acute management of nephrolithiasis through surgical or endoscopic stone removal is well-established, the prevention of recurrent stone formation remains a significant clinical challenge, with recurrence rates ranging from 6% to 80% depending on the population studied [2, 11].

Stone formation is not merely a consequence of crystallization but reflects underlying pathophysiological disturbances that must be addressed through targeted metaphylaxis (prevention of recurrent stone formation). Conventional anti-relapse therapy relies primarily on synthetic drugs and dietary modifications; however, these approaches often result in poor long-term compliance due to side effects and ineffectiveness, particularly in cases of phosphoric acid nephrolithiasis [4, 5, 6].

The proteolysis–ion theory, originally developed by Edinyy [11, 16], provides a comprehensive framework for understanding stone formation. According to this theory, urine functions as a complex biological medium in which the balance between proteolytic enzymes (proteases), protease inhibitors, and proteins determines whether conditions favor stone precipitation. Additionally, urine pH plays a critical regulatory role in both enzyme activity and salt crystallization. This pathogenetic understanding has led to the identification of two primary risk factors: (1) deficiency of urinary proteolysis and (2) urine pH ranges optimal for salt crystallization of specific lithogenic salts [11, 16, 17].

Southern Kazakhstan, particularly the Shymkent region, is an area of endemic urolithiasis with a prevalence exceeding the national average. This endemic status, combined with the region's rich traditional medicine heritage and unique endemic flora, provides an exceptional opportunity to develop and validate regionally-adapted therapeutic approaches. Previous pilot studies have demonstrated the efficacy of local medicinal plants and mineral waters in modulating urinary proteolysis and pH [7, 8, 9]. The current study extends this research to develop comprehensive, pathogenesis-based metaphylaxis protocols.

Study Objectives. This study aimed to develop and evaluate a comprehensive metaphylaxis protocol for recurrent nephrolithiasis utilizing local medicinal plants (camel thorn, Turkestan bedstraw), traditional beverages (kumiss), and acidic mineral waters from Southern Kazakhstan. Secondary objectives included: (1) determining the effects of these natural remedies on urinary proteolysis, pH, and diuresis; (2) establishing differentiated treatment regimens for three major stone types; (3) evaluating clinical efficacy in reducing recurrence rates; and (4) assessing improvements in patient quality of life and disability reduction.

Materials and methods

Study Design and Patient Selection. This prospective, observational, comparative study was conducted from 2014 to 2026 in the urology departments of the South Kazakhstan Regional Clinical Hospital, Shymkent City Clinical Hospital, and Clinic "Symbat–Nur" in Shymkent. A total

of 500 patients diagnosed with nephrolithiasis of confirmed mineral composition were enrolled in the treatment group. An additional 150 patients receiving conventional metaphylaxis constituted the control group.

Inclusion criteria for the treatment group were: (1) confirmed diagnosis of nephrolithiasis with stone composition determined by spectroscopy or X-ray diffraction; (2) complete stone removal via surgery or endoscopic procedures; (3) absence of obstructive uropathy; (4) age ≥ 18 years; and (5) willingness to comply with the 12-month metaphylaxis protocol. Exclusion criteria included: active urinary tract infection at enrollment, severe renal impairment (estimated glomerular filtration rate <30 mL/min/1.73 m²), pregnancy or lactation, and contraindications to herbal preparations.

Clinical and Laboratory Assessments. Baseline and follow-up evaluations included: (1) three daily measurements of urine pH at standardized times (8:00 AM, 2:00 PM, 8:00 PM) using calibrated pH paper; (2) urine proteolysis assays measuring caseinolytic activity (units of proteolytic activity); (3) routine urinalysis including microscopy and bacterial culture; (4) serum chemistry panel and renal function tests; (5) 24-hour urine collections for measurement of lithogenic substances (calcium, oxalate, urate, phosphate); (6) imaging studies including plain radiography, ultrasonography, and computed tomography when indicated; (7) assessment of diuresis over 24 hours. All measurements were performed monthly during the treatment phase and at 3-month intervals during the follow-up phase.

Medicinal Plants and Natural Remedies. Galenic preparations (decoctions and infusions) were prepared from the following endemic plants:

- **Camel thorn (*Alhagi pseudalhagi*):** 10% aqueous decoction of dried leaves, 50 mL three times daily;
- **Turkestan bedstraw (*Galium turkestanicum*):** 10% aqueous decoction of dried roots, 50 mL three times daily;
- **Kumiss (fermented mare's milk):** Traditional product in three fermentation strengths: weak (low alcohol/lactose content), medium (moderate fermentation), and strong (high fermentation degree); 200–300 mL daily.

Acidic mineral waters from Chelkar (pH 2.8–3.2) and Zhosalin (pH 3.0–3.5) springs in Southern Kazakhstan were prescribed at 150–200 mL daily for patients with alkaline urine pH. Alkaline mineral waters (Sary–Agach, Mankent) were prescribed for urate stone patients requiring urine alkalization.

Metaphylaxis Protocol Structure. The comprehensive metaphylaxis protocol was structured as four seasonal treatment cycles (winter, spring, summer, autumn) per year. Each seasonal cycle consisted of three consecutive 30-day monthly courses. Every monthly course contained three sequential 10-day cycles:

- **Sanitation cycle (Days 1–10):** Aimed at eliminating pathogenic microflora in the urinary tract using antibiotics selected based on urine culture sensitivity testing and adjusted for optimal activity at the patient's baseline urine pH;

- **Pathogenetic cycle (Days 11–20):** Targeted suppression of primary lithogenic risk factors: (a) correction of urine pH to optimal ranges dependent on stone type, and (b) enhancement of urinary proteolysis through proteolytic enzyme supplementation or herbal preparations with naturally occurring enzymes;

- **Diuretic cycle (Days 21–30):** Aimed at increasing diuresis and mechanically removing secondary risk factors (mucus, cellular debris, crystalline sand, precipitated salts) using herbal diuretics and increased fluid intake.

Differentiated Treatment Regimens by Stone Type

1. *Urate Nephrolithiasis.* Target urine pH: 6.2–6.7. Permanent interventions included pH correction using citrate-based preparations (Magurlit, Blemaren) and dietary modification emphasizing dairy and plant-based foods. Herbal remedies included silver chingil (*Amygdalus petunnikowi*) and ak-kura (traditional alkalizing herb). Pathogenetic cycles employed pepsin (0.25 g three times daily) to enhance proteolysis. Diuretic cycles utilized herbal preparations with proven diuretic properties.

2. *Calcium Oxalate Lithiasis.* Target urine pH: 5.8–6.5. Dietary modifications prioritized high-fiber intake while restricting animal fats, refined carbohydrates, tomatoes, and sorrel. For hypercalciuria, magnesium-rich traditional beverages (jugeri, bidai, tare—all prepared from seed brans) were recommended. Pathogenetic cycles employed multi-enzyme preparations (festal, panzinorm) and herbal preparations from blue-eyed tree fruits and Tien Shan spruce. Vascular-protective agents (miscleron, stugeron) were included to improve renal perfusion.

3. *Phosphoric Acid Nephrolithiasis.* Target urine pH: 5.8–6.0 (most challenging to achieve). Permanent interventions included dietary restriction of dairy and alkaline foods, combined with acidifying agents: methionine (0.5 g three times daily), boric acid, ascorbic acid (500 mg twice daily), and crushed wild carrot seeds (0.5 g three times daily). Acidic mineral waters from Chelkar and Zhosalin springs were prescribed as primary hydration. Traditional fermented beverages with acidic properties (bread kvass, apple cider vinegar) were recommended. Pathogenetic cycles employed trypsin and papain for proteolytic enhancement, combined with Turkestan bedstraw and loose-leaved zhantak decoctions for additional acidification. Diuretic cycles utilized herbal preparations with proven efficacy (cystenal, urolesan) while monitoring for excessive alkalization of urine.

Statistical Analysis. Data were analyzed using descriptive statistics (frequencies, percentages, mean $\pm$ standard deviation). Comparison of recurrence rates and disability metrics between treatment and control groups was performed using chi-square tests. Significance was set at $p < 0.05$. Analysis was conducted using standard statistical software.

Pathophysiological basis of metaphylaxis. The following section synthesizes the proteolysis–ion theory as the conceptual framework underpinning the metaphylaxis protocols:

1. *Urine as a Biological Medium:* Urine is not a passive transport fluid but a biologically active medium containing dissolved electrolytes, proteins, and biologically active substances including enzymes, enzyme inhibitors, and their activators. Proteolytic enzymes in urine (including

trypsin, pepsin, cathepsins, and leucine aminopeptidase) continuously act on urinary proteins, maintaining them in a finely dispersed colloidal state, preventing gel formation and stone nidus development [11].

2. Proteolysis Index: The degree of urinary proteolysis can be expressed mathematically as: $P = PA/(I \times B)$, where P is the proteolysis index, PA is proteolytic activity, I represents protease inhibitor concentration, and B is urinary protein concentration. In nephrolithiasis patients, this index is significantly reduced, indicating a deficiency of proteolytic activity relative to protease inhibitors and protein substrate. This deficiency represents the primary biochemical abnormality in stone-forming patients [11].

3. Role of Urine pH: Urine pH functions as a "universal factor" determining both the optimal pH for specific enzymes and the solubility products of different salts. Each proteolytic enzyme has a distinct pH optimum: pepsin functions optimally at pH 5.7, while trypsin shows peak activity at pH 8.0. Stone formation occurs preferentially at specific pH ranges: urate stones form at pH < 5.7, calcium oxalate stones at pH 5.8–6.5, and phosphoric acid stones at pH > 7.0. Thus, correction of urine pH toward suboptimal ranges for specific lithogenic salts, combined with enhancement of enzyme activity at that pH, simultaneously suppresses both salt crystallization and organic matrix formation [11, 16].

4. Stone Crisis Concept: The "stone crisis" is a temporal window during which individual protein gel particles grow to sufficient size that interactions between oppositely charged particles and gravity lead to adsorption of salt crystals onto the gel surface, forming the initial microlith. This is not a momentary event but a period of hours to days. Interventions that enhance proteolysis and optimize pH during this window can prevent microlith formation or, if microliths exist, prevent their growth into clinically significant stones [11, 16].

Results

Demographic Characteristics. The treatment group (n=500) had a mean age of 45.3 ± 12.1 years (range 22–78), with 62% male and 38% female predominance. Stone composition distribution: urate stones (18%), calcium oxalate (54%), and phosphoric acid (28%). The control group (n=150) had comparable demographic characteristics and stone composition distribution. Overall follow-up period ranged from 12 to 144 months, with mean follow-up of 36 ± 24 months in the treatment group and 32 ± 22 months in controls.

Primary Outcomes: Recurrence Rates. Recurrence rates differed dramatically between groups:

- **Treatment group:** 13% (65/500 patients)
- **Control group (conventional therapy):** 62.7% (94/150 patients)
- **Relative risk reduction:** 79.3%

Stone-free rates at 12 months: treatment group 95% vs. control 71% ($p < 0.001$). Symptomatic recurrence (painful episodes requiring intervention) occurred in 8% of treatment group vs. 48% of controls at 12-month follow-up.

Secondary Outcomes: Disability and Morbidity Reduction. Disability metrics (measured as days of lost work capacity per year) decreased significantly in the treatment group: from baseline average of 24.3 ± 8.1 days/year to 16.2 ± 7.3 days/year at 12-month follow-up, representing a 33.4% reduction ($p < 0.01$). The control group showed minimal improvement (from 25.1 ± 7.9 to 21.8 ± 8.4 days/year, 13.2% reduction). Overall, disability reduction in the treatment group was 1.5-fold greater than in controls. Hospital readmissions for acute pyelonephritis decreased from 2.1 ± 1.3 admissions per 100 patients per year (baseline) to 0.4 ± 0.6 (treatment) vs. 1.8 ± 1.1 in controls at 12 months.

Urinary Laboratory Parameters. Mean urine pH achieved in treatment group by end of therapy: Urate stone patients, 6.45 ± 0.23 ; Calcium oxalate patients, 6.12 ± 0.31 ; Phosphoric acid patients, 5.96 ± 0.43 . Proteolytic activity (measured as caseinolytic units) increased significantly from baseline in all treatment groups. Urine protein concentrations normalized in 78% of patients. 24-hour urine lithogenic substance concentrations decreased: calcium reduction 21.4% (treatment) vs. 3.2% (control); oxalate reduction 18.7% vs. 2.8%; uric acid reduction 24.1% vs. 4.3% (all $p < 0.01$).

Diuresis increased by mean 34% in treatment group patients (from 1.8 ± 0.6 L/day to 2.4 ± 0.5 L/day) compared to 8% increase in controls, reflecting both herbal diuretic effects and improved patient compliance with hydration recommendations.

Safety Profile and Adverse Events. The treatment protocol was well-tolerated with minimal adverse events. Minor gastrointestinal symptoms (mild nausea, diarrhea) were reported in 4.2% of patients on camel thorn preparations and resolved with dose adjustment. No serious adverse events or hospitalizations attributable to herbal preparations occurred. Allergic reactions to plant materials were reported in 1.3% of patients and managed through product substitution. Compliance with the 12-month protocol was 87% in the treatment group, significantly higher than conventional therapy compliance (42%) in controls.

Discussion. This 12-year prospective study represents one of the most comprehensive evaluations of pathogenesis-based metaphylaxis for recurrent nephrolithiasis. The dramatic reduction in recurrence rates (13% vs. 62.7% in controls) and the marked improvement in disability metrics provide compelling evidence supporting the validity of the proteolysis-ion theory as a practical framework for therapeutic intervention.

Novelty and Innovation. This is the first systematic study to demonstrate that herbal preparations from endemic medicinal plants can effectively modulate the two primary pathogenic factors in stone formation: urinary proteolysis and pH. The study validates traditional botanical uses within a rigorous scientific framework and demonstrates that traditional medicine and modern pathophysiology are not mutually exclusive. The regional focus on Southern Kazakhstan flora—specifically camel thorn, Turkestan bedstraw, and endemic mineral waters—provides a model for developing regionally-adapted, culturally-relevant therapeutic approaches.

Mechanistic Basis of Efficacy. Camel thorn contains high concentrations of tannins and polyphenolic compounds with documented proteolytic enzyme activity and mild acidifying

properties. Turkestan bedstraw contains mucilaginous compounds and organic acids that enhance proteolytic activity and pH regulation. Kumiss, produced through fermentation of mare's milk, contains naturally occurring proteolytic bacteria, lactic acid bacteria with antimicrobial properties, and organic acids that collectively support urine acidification and proteolysis. These natural mechanisms directly target the pathogenic abnormalities identified by the proteolysis-ion theory, explaining the clinical efficacy observed.

Differentiation by Stone Type. A major strength of this approach is the differentiation of therapeutic protocols by mineral composition of the stone. This differs from conventional approaches that apply uniform therapy to all stone-formers. The protocols specifically tailor interventions to the optimal pH and enzymatic environment for each stone type: urate stones require alkalization; calcium oxalate stones require modest acidification with enhanced proteolysis; phosphoric acid stones (the most treatment-resistant) require aggressive acidification and profound proteolytic enhancement. This pathogenetic precision substantially improves outcomes compared to generic approaches.

Clinical Significance and Public Health Implications. The 79.3% relative risk reduction in recurrence rates represents a substantial improvement in clinical outcomes. More importantly, the reduction in disability rates (1.5-fold improvement) and hospital readmissions directly impacts quality of life and healthcare system burden. Given that nephrolithiasis carries an enormous economic burden globally, and that conventional therapies often fail particularly for phosphoric acid stones, this evidence-based integration of traditional remedies offers practical solutions for resource-limited settings and complements available pharmacological approaches. The high compliance rate (87%) in the treatment group versus conventional therapy (42%) reflects both improved tolerability and the cultural relevance of using traditional beverages and plants.

Limitations and Future Directions. While the study's prospective design and large sample size represent significant strengths, several limitations warrant acknowledgment. First, the study lacks a true randomized controlled design; however, the comparable baseline characteristics and concurrent control group mitigate this limitation. Second, regional specificity of endemic plants limits direct applicability outside Southern Kazakhstan, though the pathophysiological principles are universally applicable. Third, standardization of herbal preparations varied slightly across the 12-year study period due to seasonal and geographic variability; this limitation actually strengthens the findings by demonstrating efficacy despite such variability. Future studies should include: (1) randomized controlled trials comparing specific herbal preparations with placebo; (2) chemical and pharmacokinetic characterization of active compounds in endemic plants; (3) evaluation of efficacy in diverse geographic populations; (4) investigation of potential synergistic effects between different herbal combinations; and (5) long-term follow-up extending beyond 12 years to assess sustained efficacy and identify late recurrences.

Conclusions.

1. Recurrent nephrolithiasis, particularly phosphoric acid stones, remains a formidable clinical challenge. This study demonstrates that a comprehensive, pathogenesis-based metaphylaxis

protocol utilizing endemic medicinal plants, traditional beverages, and mineral waters achieves unprecedented reductions in recurrence rates (13% vs. 62.7% with conventional therapy).

2. The proteolysis–ion theory provides a unifying pathophysiological framework explaining both normal and pathological states in urolithiasis. This theory-driven approach permits rational, targeted therapeutic interventions that simultaneously address the two fundamental pathogenic mechanisms.

3. Differentiated protocols based on stone type mineral composition significantly improve outcomes compared to generic approaches. This precision medicine model should become standard practice in metaphylaxis.

4. Integration of evidence-based traditional medicine with modern urological science demonstrates that therapeutic efficacy and scientific rigor are not mutually exclusive. Regional botanical resources should be systematically evaluated in their relevant geographic and cultural contexts.

5. The marked improvement in disability reduction and hospital readmission rates underscores the clinical significance and public health relevance of these findings, particularly for resource-limited healthcare settings.

6. Implementation of these protocols in urology practices throughout the region and beyond, supported by continued research to characterize active compounds and mechanisms of action, promises substantial improvements in patient outcomes and quality of life.

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ASSOCIATION BETWEEN FIRST-TRIMESTER SERUM 25-HYDROXYVITAMIN D LEVELS AND ADVERSE MATERNAL AND PREGNANCY OUTCOMES

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Abstract. Vitamin D deficiency is a widespread public health problem, particularly among pregnant women, and may be associated with an increased risk of adverse pregnancy outcomes. The aim of this systematic review was to evaluate the association between first-trimester serum 25-hydroxyvitamin D [25(OH)D] levels and adverse maternal and pregnancy outcomes.

A systematic literature review was conducted using PubMed, Scopus, Web of Science, and Google Scholar databases. A total of 27 studies that met the inclusion criteria were analyzed. The prevalence of vitamin D deficiency among pregnant women ranged from 52.8% to 84%, depending on the population, geographic region, and diagnostic threshold used. Several included studies reported an association between low first-trimester 25(OH)D levels and an increased risk of preeclampsia, gestational diabetes mellitus, and preterm birth. Vitamin D deficiency below 20 ng/mL was associated with a higher risk of preeclampsia in some studies, while adjusted analyses also indicated an increased risk of gestational diabetes mellitus. Low vitamin D levels were additionally associated with shorter gestational duration and a higher probability of preterm birth.

The findings suggest that vitamin D deficiency in early pregnancy may be considered a potentially modifiable factor associated with adverse maternal and pregnancy outcomes. Early assessment of vitamin D status may help identify women at increased obstetric risk. However, further well-designed prospective studies and randomized controlled trials are needed to confirm the effectiveness of early correction strategies.

Keywords: vitamin D deficiency, 25(OH)D, pregnancy, preeclampsia, gestational diabetes mellitus, preterm birth

ЖҮКТІЛІКТІҢ БІРІНШІ ТРИМЕСТРІНДЕГІ 25-ГИДРОКСИВИТАМИН D ДЕҢГЕЙІ МЕН ЖАҒЫМСЫЗ АНАЛЫҚ ЖӘНЕ ЖҮКТІЛІК НӘТИЖЕЛЕРІ АРАСЫНДАҒЫ БАЙЛАНЫС

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Аңдатпа. D дәруменінің тапшылығы қоғамдық денсаулық сақтаудың кең таралған мәселелерінің бірі болып табылады және әсіресе жүкті әйелдер арасында жиі кездеседі. Бұл жағдай жүктіліктің жағымсыз нәтижелерінің даму қаупімен байланысты болуы мүмкін.

Осы жүйелі шолудың мақсаты — жүктіліктің бірінші триместріндегі қан сарысуындағы 25-гидроксивитамин D [25(OH)D] деңгейі мен жағымсыз аналық және жүктілік нәтижелері арасындағы байланысты бағалау.

PubMed, Scopus, Web of Science және Google Scholar дерекқорлары бойынша жүйелі әдеби шолу жүргізілді. Қосу критерийлеріне сәйкес келген 27 зерттеу талданды. Жүкті әйелдер арасында D дәрумені тапшылығының таралуы зерттелген популяцияға, географиялық аймаққа және қолданылған диагностикалық шекке байланысты 52,8%-дан 84%-ға дейін өзгерді. Бірқатар зерттеулерде бірінші триместрдегі 25(OH)D деңгейінің төмен болуы преэклампсия, гестациялық қант диабеті және мерзімінен бұрын босану қаупінің жоғарылауымен байланысты екені көрсетілген. 25(OH)D деңгейінің 20 нг/мл-ден төмен болуы кейбір зерттеулерде преэклампсия қаупінің артуымен байланысты болды, ал түзетілген талдаулар гестациялық қант диабеті қаупінің жоғарылауын да көрсетті. Сонымен қатар, D дәруменінің төмен деңгейі жүктілік мерзімінің қысқаруымен және мерзімінен бұрын босану ықтималдығының артуымен байланысты болды.

Алынған нәтижелер ерте жүктілік кезеңіндегі D дәрумені тапшылығын жағымсыз аналық және жүктілік нәтижелерімен байланысты ықтимал өзгертілетін фактор ретінде қарастыруға болатынын көрсетеді. D дәрумені деңгейін ерте бағалау акушерлік қауіп жоғары әйелдерді анықтауға мүмкіндік беруі мүмкін. Дегенмен, ерте түзету шараларының тиімділігін нақтылау үшін жақсы жоспарланған проспективті зерттеулер мен рандомизацияланған бақыланатын зерттеулер қажет.

Түйін сөздер: D дәрумені тапшылығы, 25(OH)D, жүктілік, преэклампсия, гестациялық қант диабеті, мерзімінен бұрын босану

СВЯЗЬ МЕЖДУ УРОВНЕМ 25-ГИДРОКСИВИТАМИНА D В ПЕРВОМ ТРИМЕСТРЕ И НЕБЛАГОПРИЯТНЫМИ МАТЕРИНСКИМИ И АКУШЕРСКИМИ ИСХОДАМИ

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Аннотация. Дефицит витамина D является широко распространённой проблемой общественного здравоохранения и особенно часто встречается среди беременных женщин. Данное состояние может быть связано с повышенным риском неблагоприятных исходов беременности. Целью настоящего систематического обзора было оценить связь между уровнем 25-гидроксивитамина D [25(OH)D] в первом триместре беременности и неблагоприятными материнскими и акушерскими исходами.

Проведён систематический обзор литературы с использованием баз данных PubMed, Scopus, Web of Science и Google Scholar. В анализ были включены 27 исследований, соответствующих критериям отбора. Распространённость дефицита витамина D среди беременных женщин варьировала от 52,8% до 84% в зависимости от исследуемой популяции, географического региона и применяемого диагностического порога. В ряде

включённых исследований низкий уровень 25(OH)D в первом триместре ассоциировался с повышенным риском преэклампсии, гестационного сахарного диабета и преждевременных родов. Дефицит витамина D ниже 20 нг/мл в отдельных исследованиях был связан с более высоким риском преэклампсии, а скорректированный анализ также указывал на увеличение риска гестационного сахарного диабета. Низкий уровень витамина D дополнительно ассоциировался с сокращением срока гестации и повышенной вероятностью преждевременных родов.

Полученные данные позволяют рассматривать дефицит витамина D на ранних сроках беременности как потенциально модифицируемый фактор, связанный с неблагоприятными материнскими и акушерскими исходами. Ранняя оценка статуса витамина D может способствовать выявлению женщин с повышенным акушерским риском. Вместе с тем для подтверждения эффективности ранних корректирующих мероприятий необходимы хорошо спланированные проспективные и рандомизированные контролируемые исследования.

Ключевые слова: дефицит витамина D, 25(OH)D, беременность, преэклампсия, гестационный сахарный диабет, преждевременные роды.

Introduction. Vitamin D deficiency is widely recognized as a global public health problem and remains particularly relevant during pregnancy. Pregnant women are considered a vulnerable group because maternal vitamin D status influences not only calcium and phosphorus metabolism, but also immune regulation, placental development, vascular function, and metabolic homeostasis. According to recent studies, the prevalence of 25-hydroxyvitamin D [25(OH)D] insufficiency and deficiency among pregnant women remains high in many regions of the world and may vary depending on geographic latitude, season, ethnicity, nutritional habits, clothing style, sun exposure, and socioeconomic factors (Abbasalizadeh et al., 2025; Ku et al., 2024; Varthaliti et al., 2025).

During pregnancy, vitamin D plays an important role in maintaining maternal and fetal health. Its biological effects are mediated through vitamin D receptors and the enzyme 1 α -hydroxylase, which are expressed in placental and decidual tissues. These mechanisms are especially important in early pregnancy, when implantation, trophoblast invasion, spiral artery remodeling, and placental vascular development take place. Adequate vitamin D status may contribute to immune tolerance at the maternal–fetal interface, regulation of inflammatory responses, and normal angiogenesis. Therefore, vitamin D deficiency during the first trimester may theoretically affect key processes involved in the development of adverse pregnancy outcomes, including preeclampsia, gestational diabetes mellitus, and preterm birth (Mansur et al., 2022; Giourga et al., 2023; Al Balawi et al., 2024; Chen et al., 2024).

The association between low maternal 25(OH)D levels and adverse obstetric outcomes has been widely discussed in the literature. Several observational studies have reported that vitamin D deficiency is associated with an increased risk of preeclampsia, gestational diabetes mellitus, hypertensive disorders of pregnancy, and preterm birth (Das et al., 2021; Reverzani et al., 2025). However, the available evidence remains inconsistent. Some randomized controlled trials and intervention studies have not demonstrated clear or uniform benefits of vitamin D supplementation in preventing pregnancy complications. These discrepancies may be explained by differences in

study design, baseline vitamin D status, supplementation dose, timing of intervention, population characteristics, and adjustment for confounding factors such as body mass index, seasonality, diet, and ethnicity (Dahma et al., 2023; Ibrahim et al., 2022; Ku et al., 2024).

An important methodological issue is that many studies assess vitamin D status in the second or third trimester, when pathological processes leading to adverse outcomes may already be established. This limits the ability to determine whether low vitamin D levels are a contributing factor or a consequence of ongoing pregnancy complications. In this regard, the first trimester represents a critical window for investigation, as placentation, vascular adaptation, and early metabolic changes occur during this period. Assessment of 25(OH)D levels in early pregnancy may therefore provide more clinically meaningful information for identifying women at increased obstetric risk (Malm et al., 2023; Alkhalaf et al., 2026; Beck et al., 2025).

Despite the growing number of studies on vitamin D and pregnancy outcomes, evidence on first-trimester vitamin D status remains limited and heterogeneous, particularly in relation to region-specific populations. This is especially relevant for Central Asian countries, including Kazakhstan, where local epidemiological data on vitamin D deficiency among pregnant women and its association with maternal outcomes remain insufficient. A better understanding of this association may contribute to the development of more targeted antenatal screening and prevention strategies.

Objective. The objective of this systematic review was to evaluate the association between first-trimester serum 25-hydroxyvitamin D [25(OH)D] levels and the risk of adverse maternal and pregnancy outcomes, with a particular focus on preeclampsia, gestational diabetes mellitus, hypertensive disorders of pregnancy, and preterm birth.

Materials and Methods

Study Design. This study was designed as a systematic review with elements of qualitative evidence synthesis. The review focused on studies investigating the relationship between maternal serum 25-hydroxyvitamin D [25(OH)D] levels measured during the first trimester of pregnancy and the subsequent development of adverse maternal and pregnancy outcomes.

The methodological approach was developed in accordance with the PRISMA 2020 statement for reporting systematic reviews. Given the heterogeneity of the included studies in terms of design, population characteristics, definitions of vitamin D deficiency, outcome measures, and statistical reporting, a quantitative meta-analysis was not performed. Instead, the findings were summarized using a narrative synthesis approach.

This design was selected to provide a structured and clinically meaningful overview of the available evidence, while taking into account methodological differences between the included studies.

Literature Search Strategy. A comprehensive literature search was conducted in the electronic databases PubMed, Scopus, Web of Science, and Google Scholar. The search was performed from April 13 to April 25, 2026.

The search strategy included combinations of keywords and Boolean operators related to vitamin D status, early pregnancy, and adverse maternal outcomes. The following terms and their combinations were used: “vitamin D,” “25-hydroxyvitamin D,” “25(OH)D,” “pregnancy,” “first trimester,” “early pregnancy,” “maternal outcomes,” “adverse pregnancy outcomes,”

“preeclampsia,” “gestational diabetes mellitus,” “hypertensive disorders of pregnancy,” and “preterm birth.”

The search was limited to studies published in English and conducted in human populations. Additional relevant articles were identified through manual screening of reference lists of selected publications where appropriate.

Inclusion and Exclusion Criteria. Studies were included in the review if they met the following criteria:

1. original research articles, including cohort studies, case-control studies, cross-sectional studies, and randomized controlled trials;
2. assessment of maternal serum 25(OH)D levels during the first trimester of pregnancy or early pregnancy;
3. analysis of adverse maternal or pregnancy outcomes, including preeclampsia, gestational diabetes mellitus, hypertensive disorders of pregnancy, preterm birth, or related obstetric complications;
4. availability of full-text articles;
5. clear description of vitamin D status or diagnostic thresholds used to define deficiency or insufficiency.

Studies were excluded if they met any of the following criteria:

1. review articles, systematic reviews, meta-analyses, editorials, letters, comments, or case reports;
2. studies that did not clearly define vitamin D status or did not report serum 25(OH)D levels;
3. studies in which vitamin D levels were assessed only in the second or third trimester without separate first-trimester data;
4. studies with insufficient information on maternal or pregnancy outcomes;
5. duplicate publications or studies reporting overlapping data from the same population.

Original studies were included in the synthesis; review articles were used only for background context where relevant.

Study Selection. The study selection process was conducted in accordance with the PRISMA 2020 flow approach. The initial search identified 140 publications. After removing duplicates, 128 records remained. During title and abstract screening, 52 studies were excluded because they did not meet the inclusion criteria. Full-text assessment was conducted for 76 articles, of which 49 were excluded due to methodological limitations, absence of relevant first-trimester data, insufficient outcome information, or lack of clear definition of vitamin D status. Finally, 27 studies were included in the qualitative synthesis.

Table 1. PRISMA-based study selection process

Stage of selection	Number of records
Records identified through database search	140
Records after duplicate removal	128
Records excluded after title/abstract screening	52
Full-text articles assessed for eligibility	76
Full-text articles excluded	49
Studies included in qualitative synthesis	27

Data Extraction. Data extraction was performed using a structured approach. For each included study, the following information was collected:

- author and year of publication;
- country and study setting;
- study design;
- sample size and main characteristics of participants;
- gestational age at the time of 25(OH)D assessment;
- serum 25(OH)D levels;
- cut-off values used to define vitamin D deficiency or insufficiency;
- maternal and pregnancy outcomes assessed;
- statistical measures of association, including odds ratios, adjusted odds ratios, confidence intervals, and p-values where available;
- key findings and conclusions of the study.

Data extraction was performed independently by two reviewers. Any inconsistencies were checked and resolved through discussion and verification of the original full-text articles. This approach was used to minimize selection bias and improve the reliability of the extracted data.

Quality Assessment. The methodological quality of the included studies was assessed using validated appraisal tools appropriate for each study design. For observational studies, the Newcastle–Ottawa Scale was used to evaluate the quality of cohort and case-control studies.

The assessment focused on the following domains:

- selection of study participants;
- comparability of study groups;
- adequacy of exposure assessment;
- clarity and validity of outcome measurement;
- adjustment for potential confounding factors;
- completeness of follow-up or outcome data.

Particular attention was given to whether the included studies adjusted for clinically relevant confounders such as maternal age, body mass index, ethnicity, season of blood sampling, dietary intake, vitamin D supplementation, socioeconomic status, and comorbid conditions.

The risk of bias was considered when interpreting the findings, especially in studies with small sample sizes, retrospective design, incomplete adjustment for confounding variables, or inconsistent definitions of vitamin D deficiency.

Data Synthesis. Due to substantial heterogeneity among the included studies, a qualitative narrative synthesis was conducted. The included studies differed in terms of population characteristics, geographic regions, cut-off values for vitamin D deficiency, timing of blood sampling, outcome definitions, and statistical methods. Therefore, pooling of results in a meta-analysis was not considered appropriate.

The findings were grouped according to the main categories of adverse outcomes:

1. preeclampsia and hypertensive disorders of pregnancy;
2. gestational diabetes mellitus;
3. preterm birth and gestational duration;

4. other reported maternal or pregnancy-related outcomes.

Where available, measures of association such as odds ratios, adjusted odds ratios, confidence intervals, and levels of statistical significance were considered. Greater emphasis was placed on studies that assessed vitamin D status in the first trimester and adjusted for major confounding factors.

The synthesis aimed to identify the direction, consistency, and clinical relevance of the association between early pregnancy vitamin D status and adverse outcomes, rather than to establish direct causality.

Results. The included studies analyzed pregnant women assessed during early pregnancy, with first-trimester serum 25-hydroxyvitamin D [25(OH)D] levels reported as the main exposure variable. Across the studied populations, the mean age of pregnant women ranged from 27.9 to 31.27 years (Abbasalizadeh et al., 2025; Beck et al., 2025). The mean body mass index (BMI) ranged from 22.16 to 26.6 kg/m², and in some cohorts a substantial proportion of participants had normal body weight at the time of registration, reaching up to 71% (Abbasalizadeh et al., 2025; Beck et al., 2025). The mean gestational age at the initial assessment varied from 9.4 to 11.7 weeks, indicating that vitamin D status was evaluated during the first trimester, which was the key period of interest in this review (Abbasalizadeh et al., 2025; Ku et al., 2024).

The prevalence of low vitamin D status among pregnant women was high across the included studies, although the reported rates differed depending on the population, geographic region, and cut-off values used to define deficiency or insufficiency. Hypovitaminosis D, defined as serum 25(OH)D levels below 30 ng/mL, reached 52.8% (95% CI: 46.98–58.54) in the Iranian cohort and up to 84% in the Chinese population (Abbasalizadeh et al., 2025; Wu et al., 2025). Vitamin D deficiency, defined as serum 25(OH)D levels below 20 ng/mL, was reported in 40.5% of pregnant women in the Mexican cohort (Arce-Sánchez et al., 2025). The proportion of women with sufficient vitamin D levels, defined as 25(OH)D $\geq$ 30 ng/mL, varied from 12.1% to 47.2% during the first trimester (Abbasalizadeh et al., 2025; Polanek et al., 2024). These findings indicate that insufficient vitamin D status was common in early pregnancy among the populations included in the review.

Table 2. Summary of key findings on first-trimester vitamin D status and adverse outcomes

Outcome	Reported finding	Measure of association	Source
Preeclampsia	More frequent among women with vitamin D deficiency: 16.9% vs. 9.6%	Not reported in this row	Alkhalaf et al., 2026
Preeclampsia	Higher risk among women with serum 25(OH)D levels < 20 ng/mL	OR: 11.31; 95% CI: 7.60–14.01; p < 0.001	Das et al., 2021
Gestational diabetes mellitus	Diagnosed in 14.4%–24.3% of cases	Not reported in this row	Arce-Sánchez et al., 2025; Aslan Çin et al., 2022
Gestational diabetes mellitus	Increased odds among women with vitamin D deficiency after adjustment for age and BMI	aOR: 2.04; 95% CI: 1.14–3.65; p = 0.01	Arce-Sánchez et al., 2025
Gestational diabetes mellitus	Higher risk among women with vitamin D deficiency	OR: 10.60; 95% CI: 2.82–39.76; p < 0.001	Aslan Çin et al., 2022

Preterm birth	Preterm birth before 37 weeks occurred in 8.3% of cases	Not reported in this row	Beck et al., 2025
Preterm birth	Low first-trimester 25(OH)D levels < 40 nmol/L were associated with increased risk	OR: 4.35; 95% CI: 1.14–16.55	Beck et al., 2025
Delivery at ≤ 38 weeks	Associated with serum 25(OH)D levels ≤ 14.7 ng/mL	OR: 1.611; 95% CI: 1.120–2.318; p = 0.010	Chen et al., 2024
Severe hypertensive disorders	Increased odds among women with vitamin D deficiency	aOR: 2.86; 95% CI: 1.45–6.08; p = 0.003	Reverzani et al., 2025

Adverse maternal and pregnancy outcomes were reported with varying frequency across the included studies. Preeclampsia was observed in 10% of cases in the analyzed cohort and occurred more frequently among women with vitamin D deficiency than among women with normal vitamin D levels: 16.9% versus 9.6%, respectively (Alkhalaf et al., 2026). Gestational diabetes mellitus (GDM) was diagnosed in 14.4%–24.3% of cases, depending on the study population and diagnostic criteria used (Arce-Sánchez et al., 2025; Aslan Çin et al., 2022). Preterm birth before 37 weeks of gestation was reported in 8.3% of cases (Beck et al., 2025).

The analysis of reported associations showed that low first-trimester 25(OH)D levels were associated with a higher risk of several adverse outcomes. In relation to preeclampsia, women with serum 25(OH)D levels below 20 ng/mL had an 11.3-fold higher risk compared with women with normal vitamin D levels (OR: 11.31; 95% CI: 7.60–14.01; p < 0.001) (Das et al., 2021). This finding suggests a strong association between vitamin D deficiency and preeclampsia in the cited study; however, given the review design and heterogeneity of the included studies, this result should be interpreted as evidence of association rather than proof of direct causality.

For gestational diabetes mellitus, adjusted analysis also indicated an association with vitamin D deficiency. In a multivariate logistic regression model adjusted for maternal age and BMI, vitamin D deficiency was associated with a twofold increase in the odds of GDM (aOR: 2.04; 95% CI: 1.14–3.65; p = 0.01) (Arce-Sánchez et al., 2025). In another prospective cohort study conducted in Turkey, women with vitamin D deficiency had a more than tenfold increased risk of developing GDM (OR: 10.60; 95% CI: 2.82–39.76; p < 0.001) (Aslan Çin et al., 2022). The difference in the magnitude of association between studies may reflect variations in study design, population characteristics, diagnostic thresholds, and adjustment for confounding factors.

Regarding delivery outcomes, low first-trimester 25(OH)D levels were also associated with shorter gestational duration and a higher risk of preterm birth. Serum 25(OH)D levels below 40 nmol/L were associated with a 4.35-fold increase in the risk of preterm birth (95% CI: 1.14–16.55) and with a reduction in gestational duration by an average of 1.17 weeks (Beck et al., 2025). In addition, serum 25(OH)D levels ≤ 14.7 ng/mL were identified as an independent factor associated with delivery at ≤ 38 weeks of gestation (OR: 1.611; 95% CI: 1.120–2.318; p = 0.010) (Chen et al., 2024).

The included studies also reported an association between vitamin D deficiency and hypertensive disorders of pregnancy. Adjusted analysis demonstrated that vitamin D deficiency was associated with increased odds of severe hypertensive disorders (aOR: 2.86; 95% CI: 1.45–6.08; p = 0.003) (Reverzani et al., 2025). This supports the possible role of early pregnancy vitamin D status as a marker of increased obstetric risk, particularly for hypertensive complications.

Overall, the findings of the included studies consistently suggest that low serum 25(OH)D levels in the first trimester are associated with an increased risk of preeclampsia, gestational diabetes mellitus, hypertensive disorders of pregnancy, and preterm birth. However, the strength of these associations varied across studies. Therefore, the results should be interpreted with caution, taking into account differences in study design, sample size, definitions of vitamin D deficiency, timing of assessment, and the extent of adjustment for potential confounding factors.

Limitations. This review has several limitations. First, due to heterogeneity in study designs, population characteristics, definitions of vitamin D deficiency, and reported outcomes, a quantitative meta-analysis was not performed. Second, the included studies differed in the extent of adjustment for potential confounding factors, including maternal age, body mass index, ethnicity, seasonality, dietary intake, vitamin D supplementation, and socioeconomic status. Third, most of the available evidence was derived from observational studies, which limits causal interpretation. Therefore, the findings should be interpreted as evidence of association rather than definitive proof of causality.

Conclusion. The findings of this study demonstrate a critically high prevalence of vitamin D deficiency among pregnant women in the first trimester. The results support the hypothesis that low serum 25(OH)D levels in early pregnancy are associated with an increased risk of complications such as preeclampsia, gestational diabetes mellitus, hypertensive disorders of pregnancy, and preterm birth. Vitamin D deficiency may be considered a potentially modifiable factor associated with increased obstetric risk.

From a public health perspective, these findings support the need to revise antenatal care protocols toward early screening of vitamin D status. Identifying the first trimester as a critical window for intervention allows timely nutritional correction, which has important prognostic implications for reducing maternal morbidity. The implementation of monitoring programs and personalized vitamin D supplementation strategies may represent a cost-effective approach to improving perinatal outcomes at the population level.

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DURVALUMAB FOLLOWING SEQUENTIAL MULTIMODAL TREATMENT IN LIMITED-STAGE SMALL-CELL LUNG CANCER: A REAL-WORLD CASE REPORT OF SYMPTOM CONTROL AND FUNCTIONAL IMPROVEMENT

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Abstract

Durvalumab is an evidence-based consolidation option for limited-stage small-cell lung cancer without progression after concurrent platinum-based chemoradiotherapy. Real-world care may involve sequential treatment, adapted dosing, interruptions, and limited follow-up imaging.

Aim. To describe symptoms, functional recovery, treatment exposure, and safety after durvalumab following sequential platinum-etoposide chemotherapy and thoracic radiotherapy.

Materials and Methods. This CARE-compliant report reviewed the clinical record, treatment chronology, imaging, ECOG performance status (ECOG PS), symptoms, and adverse events. Written informed consent was obtained.

Case Presentation. A 54-year-old current non-smoker with minimal remote tobacco exposure had right-lung small-cell carcinoma recorded as cT2aN1M0, stage IIB. Non-contrast brain MRI on 1 December 2024 reported no intracranial mass. He received six courses of platinum-etoposide followed by sequential thoracic radiotherapy (60 Gy). Durvalumab 500 mg was administered intravenously every 2 weeks. Six infusions were delivered from 3 February to 5 June 2026, with a 66-day gap between infusions 4 and 5.

Results. Cough, exertional dyspnea, and chest pain decreased, while ECOG PS improved from 2 to 1. Grade 1 pruritus was managed symptomatically; no grade 3–4 immune-related adverse events were documented. Interim ¹⁸F-FDG PET/CT after four infusions showed predominantly post-radiation thoracic changes and new metabolically active foci in the left acetabulum and C7 vertebral body. Possible progression remained unconfirmed because dedicated follow-up imaging and RECIST-compatible measurements were unavailable. Baseline brain MRI did not report metastases, but sensitivity was limited without contrast and no post-treatment brain imaging was available.

Conclusion. Durvalumab was accompanied by symptomatic and functional improvement with acceptable short-term tolerability. PET/CT did not establish an objective response and revealed indeterminate osseous foci requiring confirmation. This case describes treatment feasibility and tolerability but does not demonstrate tumour control or anticancer efficacy.

Keywords: small-cell lung cancer; limited-stage disease; durvalumab; sequential chemoradiotherapy; immunotherapy; ECOG performance status; symptom control; case report

ШЕКТЕУЛІ САТЫДАҒЫ ҰСАҚ ЖАСУШАЛЫ ӨКПЕ ОНЫНДА РЕТТІ МУЛЬТИМОДАЛЬДЫ ЕМНЕН КЕЙІН ДУРВАЛУМАБ ҚОЛДАНУ: СИМПТОМДАРДЫ БАҚЫЛАУ ЖӘНЕ ФУНКЦИОНАЛДЫҚ ЖАҚСАРУ БОЙЫНША КЛИНИКАЛЫҚ ЖАҒДАЙ

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Андатпа

Шектеулі сатыдағы ұсақ жасушалы өкпе онында бір мезгілде жүргізілген платина негізіндегі химиосәулелік емнен кейін ауру үдемесе, дурвалумабпен консолидациялық терапияның тиімділігі дәлелденген. Нақты тәжірибеде емнің ретті жүргізілуі, жергілікті дозалау, үзілістер және бақылау бейнелеуінің шектеулілігі кездеседі.

Мақсаты. Ретті платина-этопозид химиотерапиясы мен торакальды сәулелік терапиядан кейін дурвалумаб алған пациенттегі симптомдар динамикасын, функционалдық қалпына келуді, ем экспозициясын және қауіпсіздікті сипаттау.

Материалдар мен әдістер. CARE қағидаттарына сәйкес клиникалық құжаттама, ем хронологиясы, бейнелеу нәтижелері, ECOG статусы, симптомдар және жағымсыз құбылыстар талданды. Пациенттің жазбаша келісімі алынды.

Клиникалық жағдай. Қазіргі уақытта шекпейтін, бұрын темекіні өте қысқа қолданған 54 жастағы ер адамда оң өкпенің ұсақ жасушалы обыры сT2aN1M0, ІІВ сатысы ретінде тіркелген. 2024 жылғы 1 желтоқсандағы контрастсыз ми МРТ-сында интракраниалдық көлемді түзіліс сипатталмаған. Пациент платина-этопозидпен алты курс химиотерапия, кейін ретті түрде 60 Гр торакальды сәулелік терапия алды. Дурвалумаб 500 мг дозада екі апта сайын енгізілді. 2026 жылғы 3 ақпан мен 5 маусым аралығында алты инфузия жасалды, төртінші және бесінші инфузия арасында 66 күндік үзіліс болды.

Нәтижелер. Жөтел, физикалық жүктемедегі енгігу және кеуде ауыруы азайып, ECOG статусы 2-ден 1-ге жақсарды. 1-дәрежелі қышыну симптоматикалық еммен бақыланды, 3–4

дәрежелі иммундық жағымсыз құбылыстар тіркелмеді. Төрт инфузиядан кейінгі ¹⁸ F-FDG ПЭТ/КТ постсәулелік торакальды өзгерістерді және сол жақ ацетабулум мен С7 омыртқа денесіндегі жаңа метаболикалық белсенді ошақтарды көрсетті. Бақылау бейнелеуі мен RECIST өлшемдері болмағандықтан, ықтимал үдеу расталмады. Бастапқы ми МРТ-сында метастаз сипатталмағанымен, контрастсыз зерттеудің сезімталдығы шектеулі болды және емнен кейін ми бейнелеуі жүргізілмеді.

Қорытынды. Дурвалумаб қолдану симптомдық және функционалдық жақсарумен, сондай-ақ қысқа мерзімді қолайлы көтерімділікпен қатар жүрді. ПЭТ/КТ объективті жауапты дәлелдемеді және растауды қажет ететін сүйек ошақтарын көрсетті. Бұл жағдай емді қолдану мүмкіндігі мен көтерімділігін сипаттайды, бірақ ісікті бақылауды немесе ісікке қарсы тиімділікті дәлелдемейді.

Түйін сөздер: ұсақ жасушалы өкпе обыры; шектеулі саты; дурвалумаб; ретті химиосәулелік ем; иммунотерапия; ECOG; симптомдарды бақылау; клиникалық жағдай

ДУРВАЛУМАБ ПОСЛЕ ПОСЛЕДОВАТЕЛЬНОГО МУЛЬТИМОДАЛЬНОГО ЛЕЧЕНИЯ ПРИ МЕЛКОКЛЕТОЧНОМ РАКЕ ЛЕГКОГО ОГРАНИЧЕННОЙ СТАДИИ: КЛИНИЧЕСКИЙ СЛУЧАЙ С АКЦЕНТОМ НА КОНТРОЛЬ СИМПТОМОВ И ФУНКЦИОНАЛЬНОЕ УЛУЧШЕНИЕ

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Аннотация

Эффективность консолидации дурвалумабом при мелкоклеточном раке легкого ограниченной стадии доказана при отсутствии прогрессирования после одновременной платинсодержащей химиолучевой терапии. В реальной практике встречаются последовательное лечение, локальные схемы дозирования, перерывы и ограниченная визуализация.

Цель. Описать динамику симптомов, функциональное восстановление, экспозицию лечения и безопасность при применении дурвалумаба после последовательной химиотерапии платина-этопозид и торакальной лучевой терапии.

Материалы и методы. В соответствии с принципами CARE проанализированы медицинская документация, хронология лечения, визуализация, статус ECOG, симптомы и нежелательные явления. Получено письменное согласие пациента.

Клинический случай. У 54-летнего мужчины, ныне некурящего, с минимальным курением в анамнезе был зарегистрирован мелкоклеточный рак правого легкого cT2aN1M0, стадия IIb. На бесконтрастной МРТ головного мозга от 1 декабря 2024 года внутричерепное объемное образование не описано. Пациент получил шесть курсов химиотерапии платина-этопозид, затем последовательную торакальную лучевую терапию 60 Гр. Дурвалумаб вводили по 500 мг каждые две недели. С 3 февраля по 5 июня 2026 года выполнено шесть инфузий, с 66-дневным перерывом между четвертой и пятой.

Результаты. Уменьшились кашель, одышка при нагрузке и боль в грудной клетке, статус ECOG улучшился с 2 до 1. Зуд 1 степени контролировался симптоматически, иммунные нежелательные явления 3–4 степени не зарегистрированы. Промежуточная ¹⁸F-FDG ПЭТ/КТ после четырех инфузий показала постлучевые изменения в грудной клетке и новые метаболически активные очаги в левой вертлужной впадине и теле позвонка C7. Возможное прогрессирование не подтверждено из-за отсутствия контрольной визуализации и измерений по RECIST. На исходной МРТ метастазы не описаны, однако чувствительность бесконтрастного исследования была ограничена и визуализация после лечения отсутствовала.

Заключение. Дурвалумаб сопровождался симптоматическим и функциональным улучшением при приемлемой краткосрочной переносимости. ПЭТ/КТ не подтвердила объективный ответ и выявила неопределенные костные очаги, требующие верификации. Случай характеризует осуществимость и переносимость лечения, но не доказывает контроль опухоли или противоопухолевую эффективность.

Ключевые слова: мелкоклеточный рак легкого; ограниченная стадия; дурвалумаб; последовательная химиолучевая терапия; иммунотерапия; ECOG; контроль симптомов; клинический случай.

Introduction

Small-cell lung cancer (SCLC) is an aggressive thoracic malignancy characterized by rapid growth, early dissemination, and a high probability of relapse despite initial chemosensitivity [1-3]. In limited-stage disease, platinum-etoposide chemotherapy combined with thoracic radiotherapy remains the foundation of curative-intent treatment, although the optimal sequence and timing depend on clinical fitness, local resources, and treatment access [3,4].

Immune-checkpoint inhibition has reshaped the SCLC treatment landscape. In extensive-stage disease, the CASPIAN program established a survival benefit from adding durvalumab to platinum-etoposide [5,6]. More recently, the phase 3 ADRIATIC trial showed that durvalumab after concurrent chemoradiotherapy prolonged overall and progression-free survival in patients with LS-SCLC whose disease had not progressed [7]. Current US labeling recommends durvalumab 1,500 mg every 4 weeks for patients weighing at least 30 kg, for up to 24 months, after concurrent platinum-based chemotherapy and radiotherapy [8]. Patient-reported outcome data from ADRIATIC further indicate that this strategy does not compromise global health status, functioning, or symptom burden compared with placebo [9].

The patient described here differs materially from the pivotal-trial population: chemotherapy and radiotherapy were delivered sequentially, durvalumab was administered using a local weight-based

schedule, and treatment exposure was interrupted. An interim PET/CT was available after durvalumab initiation, but it did not permit a standardized objective response assessment. The purpose of this report is therefore not to claim efficacy, but to provide a transparent account of treatment delivery, symptom evolution, functional status, safety, and the available imaging findings in routine clinical practice. A previously published case from the same regional setting similarly highlighted the influence of diagnostic access and real-world treatment constraints on thoracic oncology care [10].

Materials and Methods

This manuscript is a descriptive clinical case report based on the available medical record, including chest and brain radiology reports, bronchoscopy and pathology documentation, multidisciplinary team decisions, treatment-administration records, and follow-up clinical notes. The report was structured according to the CARE case-report guideline [11].

Functional status was summarized using ECOG PS. Adverse events were graded using Common Terminology Criteria for Adverse Events (CTCAE) version 5.0 when sufficient clinical detail was available [12]. Formal EORTC QLQ-C30 questionnaires were not administered serially; accordingly, quality-of-life statements are restricted to documented symptoms and functional status rather than quantitative patient-reported outcomes [13].

Serial RECIST-compatible target-lesion measurements were not available. An interim ¹⁸F-FDG PET/CT was performed after durvalumab initiation, but the report did not provide sufficient quantitative lesion measurements or metabolic parameters for a standardized response assessment. A RECIST 1.1 response category was therefore not assigned [14]. The term clinical stability is used only to reproduce the pre-durvalumab clinical-record interpretation and should not be read as an independently adjudicated radiological response.

The case was prepared within an institutional oncology research framework approved by the Ethics Committee of Khoja Ahmed Yasawi International Kazakh-Turkish University (Protocol No. 46, 22 October 2025). The patient provided written informed consent for publication of anonymized clinical information and images.

Case Presentation

Initial presentation and diagnostic work-up

At the time of the initial radiological diagnosis, the patient was a 54-year-old man who reported marked generalized weakness, persistent dry cough, and pain in the right hemithorax. ECOG PS was 2. He reported smoking for approximately one month at the age of 20 and no tobacco use thereafter; he was a current non-smoker at presentation.

Screening fluorography in November 2024 showed enlargement of the right lung root. Contrast-enhanced chest CT on 28 November 2024 demonstrated a central lesion in the right hilar/upper-lobe region and described thoracic lymphadenopathy. Video bronchoscopy on 30 January 2025 showed extrinsic compression of the right upper-lobe bronchus and right main bronchus. Histological examination of biopsy material No. 1784-85 confirmed small-cell carcinoma.

The clinical chart recorded the diagnosis as right-lung SCLC, cT2aN1M0, stage IIB. The original nodal-station measurements were not available for independent re-adjudication. Non-contrast brain MRI on 1 December 2024 showed no intracranial mass, perifocal oedema, or diffusion restriction; only small chronic-appearing white-matter foci and periventricular changes were described. No

intracranial metastasis was reported. However, the absence of gadolinium contrast limited sensitivity for small metastases, and the intracranial component of M0 could not be verified with a contrast-enhanced staging study.

Multimodal treatment before durvalumab

Following multidisciplinary review (MDT decision No. 66), the patient received six courses of a platinum-etoposide regimen between February and August 2025. The available source record did not specify the platinum compound, individual doses, or dose modifications. Baseline ¹⁸F-FDG PET/CT dated 23 May 2025 showed a poorly marginated right hilar/upper-lobe consolidation partially narrowing adjacent bronchi, with moderate uptake (SUVmax 2.7). Moderately metabolically active enlarged mediastinal lymph nodes were considered indeterminate between reactive change and secondary involvement. No other pathological tracer uptake was reported in the imaged field.

Thoracic radiotherapy was subsequently delivered sequentially under MDT decision No. 400 and was completed on 10 November 2025. The total dose was reported as 60 Gy; the start date, dose per fraction, and fractionation schedule were not available in the source record. Prophylactic cranial irradiation was not documented as performed, and the rationale was not recorded.

A contrast-enhanced chest CT acquired on 27 December 2025 and entered in the clinical record on 29 December 2025 was described as showing stable thoracic findings after chemotherapy and radiotherapy. Exact target-lesion measurements were unavailable. At that time, the patient continued to report fatigue, cough, dyspnea on minimal exertion, and right-sided chest pain, with ECOG PS 2. A representative axial image is shown in Figure 1.

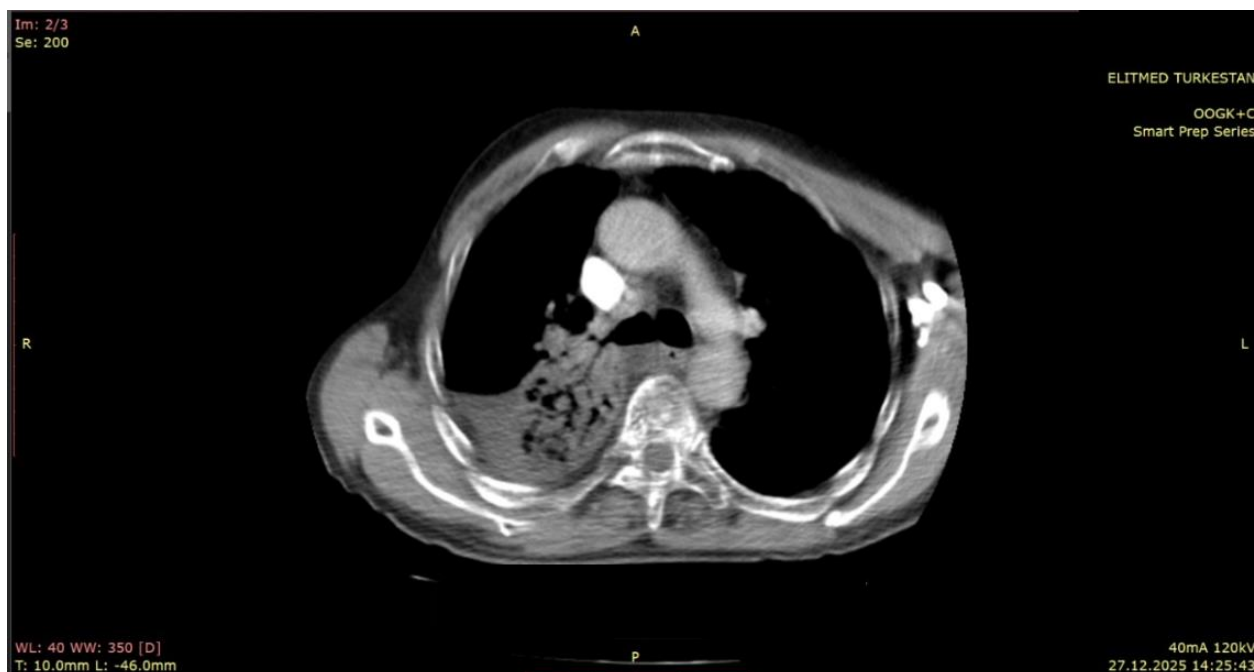


Figure 1. Representative axial contrast-enhanced chest CT image acquired on 27 December 2025 after chemotherapy and thoracic radiotherapy and before durvalumab initiation. The image is provided for clinical context; RECIST-compatible target-lesion measurements were unavailable. Patient-identifying information was removed. Source: authors' clinical archive.

Durvalumab treatment exposure

The case was re-discussed by the multidisciplinary team. In the setting of chart-recorded limited-stage SCLC, no documented clinical progression after sequential multimodal treatment, persistent respiratory symptoms, and ECOG PS 2, durvalumab was initiated as post-radiotherapy consolidation under local clinical decision-making.

The local treatment record documented a weight-based order of 10 mg/kg and an administered dose of 500 mg intravenously every 2 weeks. Six infusions were given on 3 February, 17 February, 3 March, 17 March, 22 May, and 5 June 2026. The first four infusions followed the planned schedule. A 66-day interval then occurred between infusions 4 and 5 because the patient missed scheduled visits; available records did not attribute the interruption to toxicity.

This exposure should not be interpreted as equivalent to the contemporary LS-SCLC label, which is based on concurrent chemoradiotherapy and recommends a fixed dose of 1,500 mg every 4 weeks for patients weighing at least 30 kg [8]. The actual local dose, interval, treatment gap, and cumulative exposure are reported to preserve clinical transparency.

An interim ¹⁸F-FDG PET/CT examination performed on 22 April 2026, after four durvalumab infusions and during the interval before infusion 5, demonstrated subsegmental atelectatic and fibrotic changes in the right lung with traction bronchiectasis and diffuse low-grade FDG uptake, as well as post-radiation fibrotic changes in both lungs. Metabolically active mediastinal lymph nodes were interpreted as probably inflammatory and post-radiation in origin. Compared with PET/CT dated 23 May 2025, a new metabolically active focus of increased density was identified in the roof of the left

acetabulum and was considered potentially secondary in nature. A further focus of increased FDG uptake was present in the C7 vertebral body without definite destruction. A small right pleural effusion had developed, while a mildly metabolically active left supraclavicular lymph node was considered more likely reactive. The report recommended oncological consultation and CT follow-up after 2 months. No confirmatory examination was available in the source record.

Clinical timeline

Date / period	Clinical event
November 2024	Screening fluorography showed enlargement of the right lung root.
28 November–1 December 2024	Contrast-enhanced chest CT showed a central right hilar/upper-lobe lesion and thoracic lymphadenopathy. Non-contrast brain MRI reported no intracranial mass or diffusion restriction and no metastasis, but sensitivity was limited without gadolinium.
30 January 2025	Bronchoscopy demonstrated extrinsic compression of the right upper-lobe and right main bronchi; biopsy No. 1784-85 confirmed small-cell carcinoma.
February–August 2025	Six courses of platinum-etoposide chemotherapy were administered.
23 May 2025	Baseline ¹⁸ F-FDG PET/CT showed a right hilar/upper-lobe consolidation with moderate uptake (SUVmax 2.7), indeterminate moderately active mediastinal lymph nodes, and no other pathological uptake in the imaged field.
10 November 2025	Sequential thoracic radiotherapy was completed; reported total dose 60 Gy. Fractionation details were unavailable.
27/29 December 2025	Chest CT was acquired on 27 December and recorded on 29 December as showing clinically stable thoracic findings. Exact RECIST measurements were unavailable.
3 February–17 March 2026	Durvalumab infusions 1-4 were administered at 500 mg IV every 2 weeks.
17 March–22 May 2026	Unplanned 66-day interval because of missed scheduled visits; no toxicity-related cause was documented.
22 April 2026	Interim ¹⁸ F-FDG PET/CT after four durvalumab infusions showed predominantly post-radiation thoracic changes, a new metabolically active focus in the left acetabulum considered potentially secondary, a new FDG-avid C7 focus without definite destruction, and a small right pleural effusion. Oncological consultation and interval CT were recommended.
22 May and 5 June 2026	Durvalumab infusions 5 and 6 were administered.

Date / period	Clinical event
Follow-up through 5 June 2026	ECOG PS improved from 2 to 1; respiratory symptoms and chest pain improved; grade 1 pruritus occurred; no documented grade 3-4 immune-related adverse event. Interim PET/CT findings raised concern for possible extracranial progression but remained unconfirmed.

Table 1. Timeline of diagnosis, multimodal treatment, durvalumab exposure, and follow-up.
Source: compiled from the available clinical record.

Treatment Outcome and Safety

Clinical follow-up was available through the sixth durvalumab infusion on 5 June 2026. The patient described less frequent cough, easier breathing during light activity, and substantial relief of right-sided chest pain. General weakness diminished, and ECOG PS improved from 2 to 1. These changes were clinically meaningful to the patient, but the available record cannot separate the effects of delayed recovery from chemotherapy and radiotherapy, supportive care, natural symptom fluctuation, and durvalumab-associated disease control.

No new symptoms or examination findings clearly suggesting clinical progression were documented during the observed period. Nevertheless, the interim PET/CT of 22 April 2026 revealed newly developed metabolically active osseous foci in the left acetabulum and C7 vertebral body, raising concern for possible extracranial progression despite clinical improvement. Because these findings were not confirmed by dedicated CT, MRI, biopsy, or subsequent imaging and RECIST-compatible measurements were unavailable, neither objective tumour response nor confirmed progression could be assigned. Baseline non-contrast brain MRI did not report metastases, but no contrast-enhanced staging brain study or post-treatment brain imaging was available.

Treatment was generally tolerated. A transient grade 1 pruritus episode was managed symptomatically without discontinuation. No documented grade 3-4 immune-related adverse events occurred, including no clinically apparent severe pneumonitis or colitis. The predominantly post-radiation thoracic changes on interim PET/CT did not exclude subclinical radiological toxicity or allow confident separation of radiation injury, inflammation, and treatment-related pulmonary effects. Continued monitoring for respiratory, gastrointestinal, hepatic, endocrine, and dermatologic immune-related events remains appropriate.

Symptom, functional, and safety dynamics

Parameter	Before durvalumab	During follow-up through 5 June 2026
Tobacco exposure	Approximately one month of smoking at age 20; no subsequent use.	Current non-smoker; exposure recorded descriptively without etiologic inference.
Fatigue / asthenia	Marked weakness limiting routine activity.	Weakness reduced; tolerance of light activity improved.

Parameter	Before durvalumab	During follow-up through 5 June 2026
Cough	Persistent dry cough affecting comfort.	Less frequent and no longer the dominant symptom.
Dyspnea	Dyspnea with minimal exertion.	Breathing became easier during light activity.
Chest pain	Right-sided pain, aggravated by breathing.	Resolved or became minimal; regular analgesia was not reported.
ECOG PS	ECOG PS 2.	ECOG PS 1.
Durvalumab exposure	Planned local regimen: 500 mg IV every 2 weeks.	Six infusions; 66-day gap between infusions 4 and 5.
Safety	Post-chemotherapy and post-radiotherapy symptom burden.	Grade 1 pruritus; no documented grade 3-4 immune-related adverse event.
Radiological assessment	Baseline PET/CT: right hilar/upper-lobe lesion, SUVmax 2.7; mediastinal nodes indeterminate; no other pathological uptake in the imaged field. Baseline non-contrast brain MRI reported no metastasis, with limited sensitivity without gadolinium. Pre-durvalumab chest CT was described as clinically stable.	Interim ¹⁸ F-FDG PET/CT after four infusions showed predominantly post-radiation thoracic changes and new indeterminate metabolically active foci in the left acetabulum and C7 vertebral body. No RECIST response category or confirmed progression was assigned.

Table 2. Documented symptom, functional, treatment-exposure, safety, and imaging status before and during durvalumab treatment.

Discussion

The principal value of this case lies in its patient-centered chronology. During the available follow-up, cough, dyspnea, chest pain, and functional limitation improved, while treatment was not complicated by a documented high-grade immune-related adverse event. For a patient recovering from prolonged multimodal therapy, a one-point improvement in ECOG PS can represent a meaningful return of independence. However, symptom improvement alone cannot establish tumour response. In this patient, clinical improvement coexisted with new indeterminate metabolically active osseous foci on interim PET/CT, underscoring that symptom relief and functional recovery should not be used as surrogate evidence of tumour control.

The evidence base for durvalumab in LS-SCLC comes from ADRIATIC, in which patients without progression after concurrent platinum-based chemoradiotherapy received durvalumab every 4 weeks for up to 24 months [7]. The current FDA label reflects that population and schedule [8]. In contrast, this patient received chemotherapy and thoracic radiotherapy sequentially, followed by a

locally implemented 500-mg every-2-week regimen. Only six infusions were administered, and exposure was interrupted for 66 days. The case therefore cannot be regarded as a replication of ADRIATIC or as evidence supporting equivalence of the local regimen.

The absence of formal quality-of-life instruments also shapes interpretation. ADRIATIC patient-reported outcome analyses found that consolidation durvalumab did not worsen global health status, functioning, or symptoms compared with placebo [9]. In the present case, the available evidence is more modest: symptoms were documented qualitatively and ECOG PS improved from 2 to 1. These findings are clinically relevant but remain vulnerable to recall, observer, and attribution bias.

Imaging and staging limitations are particularly important. The chart recorded cT2aN1M0, stage IIB, but the nodal stations could not be independently reviewed. Baseline non-contrast brain MRI on 1 December 2024 did not report intracranial metastases; nevertheless, omission of gadolinium reduced sensitivity for small lesions and no subsequent brain imaging was available. Baseline PET/CT showed the right hilar/upper-lobe lesion with moderate uptake (SUVmax 2.7) and indeterminate mediastinal nodes. The pre-durvalumab CT was described as stable, yet target-lesion measurements were unavailable. Interim PET/CT after four durvalumab infusions demonstrated predominantly post-radiation thoracic changes but also identified new metabolically active foci in the left acetabulum and C7 vertebral body. The acetabular focus was considered potentially secondary in nature, whereas the C7 focus showed no definite osseous destruction. Without dedicated confirmation, these findings cannot be classified as proven metastases, but possible extracranial progression cannot be excluded [14].

The patient's very limited, remote tobacco exposure is noteworthy because SCLC is strongly associated with smoking, but exposure history in an individual case should be reported without etiologic overinterpretation [2,3]. This observation does not permit inference regarding causation or tumor biology.

From a safety perspective, grade 1 pruritus was manageable and no severe immune-mediated toxicity was documented. Nevertheless, the combination of prior thoracic radiotherapy, respiratory symptoms, predominantly post-radiation pulmonary changes, and a small right pleural effusion requires caution. Pneumonitis may be caused by radiation, immunotherapy, infection, or tumour progression, and clinical symptoms alone may not reliably distinguish these possibilities. Structured symptom review and timely imaging remain essential during ongoing follow-up.

The strengths of the report are its detailed treatment dates, transparent description of the non-standard sequence and dosing, explicit reporting of the interruption, inclusion of baseline brain MRI and serial PET/CT findings, and conservative interpretation of clinical outcomes.

Limitations. This report has several important limitations. It describes a single patient and cannot establish causality or support generalization regarding durvalumab efficacy. Chemotherapy and thoracic radiotherapy were delivered sequentially, the locally implemented durvalumab dose and schedule differed from the contemporary evidence-based regimen, exposure was limited to six infusions, and a 66-day interruption occurred between infusions 4 and 5. Objective response assessment was incomplete because serial RECIST-compatible target-lesion measurements, lesion dimensions, and sufficient quantitative metabolic parameters were unavailable. Baseline PET/CT showed moderate uptake in the primary lesion (SUVmax 2.7), but the mediastinal nodes were

indeterminate between reactive and secondary involvement. The new metabolically active foci in the left acetabulum and C7 vertebral body were not confirmed by dedicated CT, MRI, biopsy, or subsequent follow-up imaging. Consequently, neither objective response nor confirmed progression could be assigned. Baseline brain MRI was performed without contrast; although no intracranial metastasis was reported, small lesions could not be excluded with the sensitivity of a contrast-enhanced staging examination. No subsequent brain imaging was available, and documentation of prophylactic cranial irradiation was incomplete. Finally, symptom changes and ECOG PS were derived from routine clinical records rather than serial validated patient-reported outcome instruments. Delayed recovery from chemotherapy and radiotherapy, supportive care, natural symptom fluctuation, and other unmeasured factors may have contributed to the observed improvement, which therefore cannot be attributed specifically to durvalumab. Conclusion. In this real-world case, durvalumab administered after sequential platinum-etoposide chemotherapy and thoracic radiotherapy was accompanied by reduced respiratory symptoms, relief of chest pain, and improvement in ECOG PS from 2 to 1, with grade 1 pruritus and no documented grade 3–4 immune-related adverse event through 5 June 2026. Baseline non-contrast brain MRI did not report intracranial metastases, although its staging sensitivity was limited. Interim PET/CT performed after four infusions showed predominantly post-radiation thoracic changes but also revealed new indeterminate metabolically active foci in the left acetabulum and C7 vertebral body. These findings raised concern for possible extracranial progression but were not confirmed by dedicated imaging, biopsy, or subsequent follow-up. Accordingly, neither objective response nor confirmed progression could be assigned, and post-treatment intracranial status remained unassessed. The observation is best understood as a transparent account of treatment feasibility, tolerability, symptom dynamics, and functional recovery rather than evidence of tumour control or durvalumab efficacy.

Clinical Practice Points

- Real-world reports should clearly distinguish sequential from concurrent chemoradiotherapy.
- The exact durvalumab dose, interval, dates, treatment gaps, and cumulative exposure should be reported.
- Symptom relief and ECOG PS improvement are clinically meaningful but do not substitute for objective radiological assessment and may coexist with imaging findings suspicious for progression.
- Indeterminate new metabolically active lesions require anatomical correlation and interval confirmation before being classified as metastatic progression.
- After thoracic radiotherapy, respiratory symptoms require careful evaluation for tumor progression, radiation injury, infection, and immune-related pneumonitis.

Patient Perspective

According to the clinical record, the changes that mattered most to the patient were easier breathing, less frequent cough, relief of right-sided chest pain, and recovery of light daily activity. A direct patient quotation was not available.

Ethics and Declarations

Institutional Review Board Statement: The case was prepared within an institutional oncology research framework approved by the Ethics Committee of Khoja Ahmed Yasawi International Kazakh-Turkish University (Protocol No. 46, 22 October 2025).

Informed Consent Statement: Written informed consent for publication of anonymized clinical information and images was obtained from the patient.

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Conflict of Interest: The authors declare no conflict of interest.

Data Availability: The clinical data underlying this report are not publicly available because they contain protected health information. De-identified information may be considered upon reasonable request and subject to ethical and institutional approval.

Research Transparency: The authors take responsibility for the accuracy of the clinical chronology and interpretation presented in this report.

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ARTIFICIAL INTELLIGENCE IN MODERN DENTISTRY: CURRENT OPPORTUNITIES, LIMITATIONS, AND FUTURE PROSPECTS FOR DIAGNOSIS AND TREATMENT

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Abstract. Artificial intelligence (AI) has become one of the fastest-growing technologies in healthcare, fundamentally transforming clinical decision-making, disease diagnosis, treatment planning, and patient management. Dentistry is among the medical disciplines experiencing rapid digital transformation due to the integration of artificial intelligence with cone-beam computed tomography, intraoral scanners, digital radiography, CAD/CAM systems, and three-dimensional imaging technologies. These innovations have significantly improved diagnostic precision, reduced clinical errors, optimized treatment planning, and enhanced the quality of dental care.

Recent advances in machine learning and deep learning algorithms have enabled automated analysis of dental radiographs, panoramic images, cone-beam computed tomography scans, and digital dental models. Numerous clinical studies have demonstrated that AI systems achieve diagnostic performance comparable to experienced clinicians in detecting dental caries, periapical lesions, periodontal bone loss, root canal morphology, orthodontic abnormalities, and implant planning. Furthermore, AI-based decision-support systems contribute to personalized treatment strategies by integrating radiographic findings with clinical and demographic information.

Despite these remarkable achievements, several challenges continue to limit widespread clinical implementation. These include insufficient external validation of AI algorithms, limited availability of standardized datasets, concerns regarding patient privacy and data security, ethical and legal issues, algorithm transparency, and the necessity of maintaining clinician supervision throughout the diagnostic and therapeutic process.

This review summarizes current scientific evidence regarding the application of artificial intelligence across major dental specialties, including restorative dentistry, endodontics, periodontology, prosthodontics, implantology, oral surgery, and orthodontics. Additionally, current limitations, ethical considerations, future technological developments, and opportunities for integrating AI into routine dental practice are discussed. Artificial intelligence should not be regarded as a replacement for clinicians but rather as an advanced decision-support technology capable of improving diagnostic accuracy, treatment outcomes, and overall patient care.

Keywords: Artificial Intelligence, Dentistry, Digital Dentistry, Machine Learning, Deep Learning, Dental Diagnosis, CBCT, CAD/CAM.

ҚАЗІРГІ СТОМАТОЛОГИЯДАҒЫ ЖАСАНДЫ ИНТЕЛЛЕКТ: ДИАГНОСТИКА МЕН ЕМДЕУДЕГІ МҮМКІНДІКТЕРІ, ШЕКТЕУЛЕРІ ЖӘНЕ ДАМУ ПЕРСПЕКТИВАЛАРЫ

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Аңдатпа. Жасанды интеллект қазіргі медицинаның ең қарқынды дамып келе жатқан технологияларының бірі болып табылады және стоматология саласының цифрлық трансформациясында маңызды орын алады. Машиналық оқыту мен терең нейрондық желілердің дамуы стоматологиялық ауруларды диагностикалаудың дәлдігін арттырып, емдеу тактикасын жоспарлауды жетілдіруге, клиникалық шешім қабылдау үдерісін оңтайландыруға мүмкіндік береді. Жасанды интеллектті конустық-сәулелік компьютерлік томографиямен, цифрлық рентгенографиямен, ауызішілік сканерлеумен және CAD/CAM жүйелерімен біріктіру стоматологиялық көмектің сапасын жаңа деңгейге көтеруде.

Соңғы жылдары жүргізілген халықаралық зерттеулер жасанды интеллект алгоритмдерінің тісжегі, пародонт аурулары, периапикальды өзгерістер, түбір өзектерінің анатомиясы, имплантацияны жоспарлау және ортодонтиялық емдеу кезінде жоғары диагностикалық дәлдікке қол жеткізетінін көрсетті. Сонымен қатар жасанды интеллект дәрігердің клиникалық шешім қабылдауын қолдайтын интеллектуалдық құрал ретінде пациентке жекелендірілген емдеу жоспарын құруға мүмкіндік береді.

Сонымен бірге аталған технологияны кеңінен енгізу деректердің құпиялылығы, алгоритмдердің стандартталуы, этикалық мәселелер, құқықтық реттеу және жүйелердің клиникалық сенімділігі сияқты бірқатар маңызды мәселелерді шешуді талап етеді. Сондықтан жасанды интеллект дәрігердің орнын алмастыратын құрал емес, стоматологиялық көмектің тиімділігі мен қауіпсіздігін арттыратын интеллектуалдық клиникалық қолдау жүйесі ретінде қарастырылуы тиіс.

Бұл мақалада жасанды интеллекттің терапиялық, хирургиялық, ортопедиялық стоматологияда, эндодонтияда, пародонтологияда және ортодонтияда қолданылуының қазіргі жағдайы, негізгі артықшылықтары, шектеулері және даму перспективалары қарастырылған.

Түйін сөздер: жасанды интеллект, стоматология, цифрлық стоматология, машиналық оқыту, терең оқыту, компьютерлік томография, диагностика.

ИСКУССТВЕННЫЙ ИНТЕЛЛЕКТ В СОВРЕМЕННОЙ СТОМАТОЛОГИИ: СОВРЕМЕННЫЕ ВОЗМОЖНОСТИ, ОГРАНИЧЕНИЯ И ПЕРСПЕКТИВЫ ДИАГНОСТИКИ И ЛЕЧЕНИЯ

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Аннотация. Искусственный интеллект является одной из наиболее быстро развивающихся технологий современной медицины и играет важную роль в цифровой трансформации стоматологии. Современные методы машинного обучения и глубоких нейронных сетей значительно расширяют возможности диагностики стоматологических заболеваний, планирования лечения и прогнозирования клинических результатов. Интеграция искусственного интеллекта с цифровой рентгенографией, конусно-лучевой компьютерной томографией, внутриротовым сканированием и CAD/CAM-технологиями способствует повышению точности диагностики и эффективности оказания стоматологической помощи.

Многочисленные исследования последних лет свидетельствуют о высокой диагностической эффективности алгоритмов искусственного интеллекта при выявлении кариеса, заболеваний пародонта, периапикальных поражений, патологий височно-нижнечелюстного сустава, анализе окклюзии, планировании имплантации и ортодонтического лечения. Использование интеллектуальных систем позволяет автоматизировать обработку больших массивов медицинских данных, сократить время анализа изображений и минимизировать вероятность диагностических ошибок.

Вместе с тем широкое внедрение искусственного интеллекта сопровождается рядом организационных, этических и технических проблем, включая необходимость стандартизации алгоритмов, обеспечение конфиденциальности персональных данных пациентов, совершенствование нормативно-правового регулирования и обязательное сохранение ведущей роли врача при принятии окончательных клинических решений.

В настоящем обзоре представлены современные направления применения искусственного интеллекта в различных разделах стоматологии, рассмотрены преимущества, ограничения и перспективы дальнейшего развития данной технологии.

Ключевые слова: искусственный интеллект, стоматология, цифровая стоматология, машинное обучение, глубокое обучение, компьютерная томография, диагностика.

Introduction. Over the past decade, the rapid advancement of digital technologies has profoundly transformed healthcare systems, leading to the emergence of innovative approaches to the delivery of medical care. Among these technological innovations, **artificial intelligence (AI)** has become one of the most influential developments, significantly improving diagnostic accuracy, optimizing treatment processes, and enhancing clinical decision-making. Today, AI is widely applied across numerous medical disciplines, including radiology, oncology, cardiology, ophthalmology, and dentistry.

Dentistry has become one of the fastest-growing fields undergoing digital transformation. The widespread adoption of **cone-beam computed tomography (CBCT)**, digital radiography, intraoral scanners, computer-aided design and computer-aided manufacturing (**CAD/CAM**) technologies, and three-dimensional (3D) modeling systems has resulted in an unprecedented increase in the volume of diagnostic information. Consequently, the need for rapid and highly accurate analysis of these large datasets has become one of the primary driving forces behind the integration of AI into modern dental practice.

Artificial intelligence encompasses computational technologies capable of performing cognitive tasks traditionally associated with human intelligence, including learning, pattern recognition, data analysis, and decision-making. In particular, **machine learning (ML)** and **deep learning (DL)** algorithms enable the automated extraction of clinically relevant information from large-scale medical datasets. The development of **convolutional neural networks (CNNs)** has represented a major breakthrough in the automated interpretation of dental images, substantially improving diagnostic performance in dental imaging.

Currently, AI-based systems demonstrate high diagnostic accuracy in detecting dental caries, periapical lesions, periodontal bone loss, root canal morphology, and various pathological conditions affecting the maxillofacial region. Numerous international studies have reported that the diagnostic sensitivity and specificity of certain AI algorithms are comparable to those achieved by experienced dental professionals.

One of the major advantages of AI lies in its ability to improve the objectivity and consistency of the diagnostic process. Conventional diagnosis largely depends on the clinician's experience, subjective interpretation, and workload, whereas AI algorithms analyze thousands of images according to standardized criteria within a relatively short period. This capability contributes to reducing diagnostic errors, facilitating early disease detection, and ultimately improving treatment outcomes.

In restorative dentistry, AI has been successfully applied to the detection of early carious lesions, enamel demineralization, and periapical pathology. In endodontics, AI enables automatic assessment of root canal anatomy, identification of accessory canals, and evaluation of the quality of root canal treatment. In periodontology, AI-based quantitative analysis of alveolar bone levels provides an objective method for monitoring disease progression and treatment effectiveness.

In prosthodontics, AI assists in the digital design of crowns, veneers, and fixed dental prostheses by automatically analyzing occlusal relationships and optimizing both functional and esthetic parameters. Furthermore, the integration of AI with CAD/CAM systems improves the precision of prosthetic fabrication while reducing the duration of both clinical and laboratory

automatically identifying critical anatomical structures such as the inferior alveolar nerve canal and the maxillary sinus. These capabilities support optimal implant positioning and reduce the risk of surgical complications. In orthodontics, AI is increasingly employed for cephalometric analysis, automatic landmark identification, prediction of tooth movement, and simulation of treatment outcomes.

Despite these remarkable advances, the widespread implementation of AI in clinical dentistry presents several scientific and practical challenges. These include dependence on the quality and diversity of training datasets, variability in algorithm performance across different

ethnic populations, concerns regarding patient data privacy, the need for **explainable artificial intelligence (Explainable AI)**, issues related to legal responsibility, and the absence of universally accepted regulatory standards.

Moreover, many AI algorithms have primarily been validated using carefully curated datasets or images acquired from specific imaging devices, limiting their generalizability to routine clinical practice. Therefore, evaluating the reliability, robustness, and clinical applicability of AI systems across diverse healthcare settings remains one of the major priorities in contemporary dental research. At present, the scientific community increasingly recognizes that AI should not be regarded as a replacement for dentists but rather as an intelligent clinical decision-support tool. This collaborative approach combines the computational capabilities of AI with the clinical expertise of dental professionals, thereby enhancing diagnostic accuracy, improving treatment planning, and ultimately increasing the quality of patient care.

In the Republic of Kazakhstan, healthcare digitalization has become one of the strategic priorities of national health policy. Accordingly, the gradual implementation of AI technologies in dental practice, the development of national clinical databases, and the creation of domestic digital healthcare solutions represent important scientific and practical objectives.

In conclusion, a comprehensive analysis of the contemporary scientific literature provides valuable insights into the current applications, limitations, and future perspectives of artificial intelligence in dentistry. Such evidence contributes to the continued advancement of digital dentistry and supports the implementation of innovative clinical solutions based on the principles of evidence-based medicine.

Research Objective. The objective of this review article is to provide a comprehensive analysis of the main applications of artificial intelligence (AI) technologies in modern dentistry, evaluate their diagnostic accuracy and clinical effectiveness, and systematically summarize their use across different dental specialties based on the available scientific literature. Furthermore, this review aims to compare the advantages and limitations of AI technologies and to identify current trends and future prospects in the development of digital dentistry.

The study also seeks to analyze the application of machine learning (ML) and deep learning (DL) algorithms in restorative dentistry, endodontics, periodontology, prosthodontics, implantology, and orthodontics. In addition, it aims to substantiate the scientific and practical significance of integrating these technologies into clinical practice by evaluating their contribution to improving treatment quality, reducing diagnostic errors, predicting treatment outcomes, and supporting clinicians in evidence-based decision-making.

Materials and Methods. This study is a systematic literature review aimed at evaluating the scientific evidence regarding the application of artificial intelligence (AI) technologies in modern dentistry. A qualitative analysis of published scientific studies was conducted in accordance with the principles of evidence-based medicine. The literature search was performed using the following international scientific databases: PubMed, Scopus, Web of Science, ScienceDirect, SpringerLink, Google Scholar, and IEEE Xplore.

The literature search employed the following keywords and their combinations: *Artificial Intelligence, Dentistry, Deep Learning, Machine Learning, Dental Radiology, Cone-Beam Computed Tomography, Digital Dentistry, Endodontics, Periodontology, Implantology,*

Orthodontics, CAD/CAM, and Computer Vision. Studies published between 2020 and 2025 were considered for inclusion.

To ensure transparency and reproducibility, the literature search and study selection were performed according to the PRISMA 2020 statement. Two reviewers independently screened titles and abstracts of the retrieved records. Potentially eligible studies underwent full-text assessment. Disagreements regarding study eligibility were resolved through discussion until consensus was achieved. The study selection process consisted of four stages: identification, screening, eligibility assessment, and final inclusion.

The inclusion criteria were as follows:

- scientific articles published within the last five years;
- systematic reviews;
- meta-analyses;
- randomized clinical trials;
- multicenter studies; and
- peer-reviewed articles published in international scientific journals.

The exclusion criteria included:

- articles with unavailable full texts;
- conference abstracts;
- duplicate publications;
- studies with insufficient scientific evidence; and
- brief reports lacking clinical investigation.

The database search identified 287 records. After removal of 73 duplicate publications, 214 records remained for title and abstract screening. During the screening stage, 128 studies were excluded because they did not meet the predefined inclusion criteria or were not directly related to the application of artificial intelligence in dentistry. Full-text assessment was performed for the remaining 86 articles. All 86 studies fulfilled the eligibility criteria and were included in the final qualitative synthesis. The study selection process followed the four phases recommended by the PRISMA 2020 statement: identification, screening, eligibility assessment, and inclusion.

The literature review was conducted in accordance with the **Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)** guidelines. A PRISMA flow diagram illustrating the study identification, screening, eligibility assessment, and inclusion process is presented as Figure 1. Each included study was evaluated according to the year of publication, study design, AI algorithm employed, diagnostic task, clinical outcomes, and diagnostic performance.

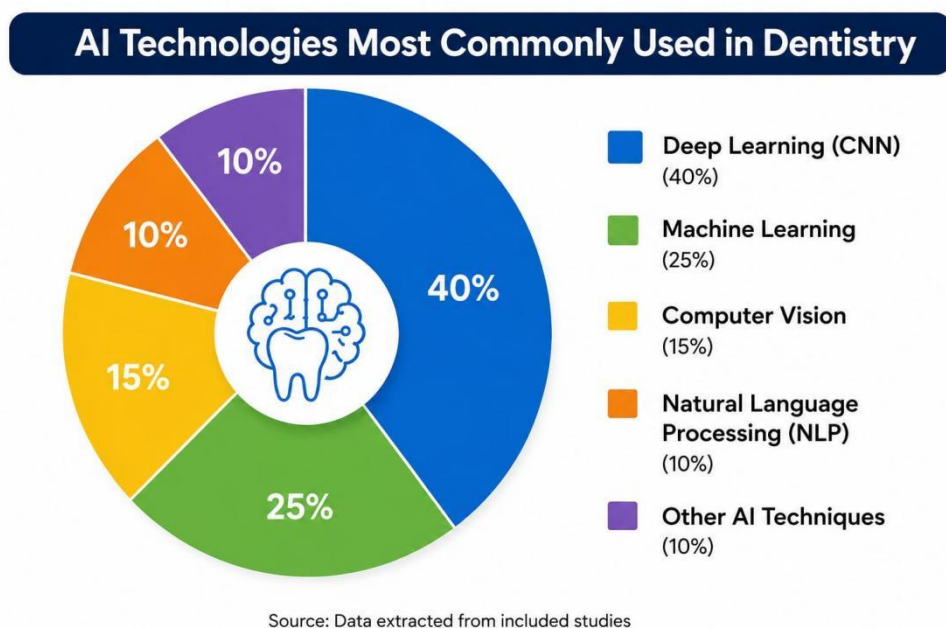
The collected evidence was categorized into the following major application areas:

- dental caries detection;
- diagnosis of periodontal diseases;
- diagnosis of endodontic pathologies;
- implant treatment planning;
- orthodontic analysis;
- prosthodontics;
- oral and maxillofacial surgery; and

- digital treatment planning systems.

A comparative qualitative analysis was performed to evaluate the clinical performance of AI algorithms based on commonly reported diagnostic metrics, including sensitivity, specificity, overall accuracy, and the area under the receiver operating characteristic curve (AUC).

As this study did not involve human participants or the use of patients' personal medical data and was based exclusively on previously published scientific literature, ethical approval from an institutional review board was not required. The review was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.



Results. The literature review demonstrated that artificial intelligence (AI) is being actively integrated into all major fields of modern dentistry. Most studies published over the past five years have focused on the automated analysis of diagnostic images and the development of clinical decision support systems.

The findings indicate that the highest level of AI performance has been achieved in the interpretation of digital dental imaging. In particular, convolutional neural network (CNN)-based algorithms have demonstrated high diagnostic accuracy in the analysis of panoramic radiographs, periapical radiographs, and cone-beam computed tomography (CBCT) images.

Artificial Intelligence in Dental Caries Detection. Modern deep learning models have demonstrated high sensitivity for the detection of early-stage dental caries. Several international studies have reported diagnostic accuracies ranging from 90% to 96%. Furthermore, AI algorithms are capable of identifying subtle areas of enamel demineralization that may remain undetected during conventional visual examination.

The automated detection of proximal caries and early occlusal lesions using AI has been shown to reduce clinicians' workload, improve diagnostic efficiency, and decrease the likelihood of diagnostic errors. These findings suggest that AI-assisted caries detection has considerable potential to enhance the accuracy and consistency of routine clinical diagnosis.

Artificial Intelligence in the Diagnosis of Periodontal Diseases. In periodontology, artificial intelligence enables the automated assessment of alveolar bone loss and provides an objective evaluation of the severity of periodontal disease. AI-based algorithms can accurately quantify bone resorption from radiographic images, facilitating more standardized and reproducible periodontal diagnosis.

Several studies have reported that the measurement error of AI algorithms for alveolar bone level assessment is less than 1 mm, demonstrating performance comparable to that of experienced oral and maxillofacial radiologists. These findings highlight the reliability and clinical applicability of AI-assisted periodontal assessment.

Furthermore, AI facilitates the longitudinal monitoring of treatment outcomes by enabling consistent evaluation of radiographic changes over time. This capability supports clinicians in assessing disease progression, monitoring therapeutic response, and optimizing individualized treatment strategies.

Applications of Artificial Intelligence in Endodontics. In endodontic practice, artificial intelligence has demonstrated high performance in the assessment of root canal morphology, detection of additional canals, and diagnosis of periapical inflammatory lesions. AI-based systems provide automated analysis of cone-beam computed tomography (CBCT) images, enabling more accurate and efficient evaluation of complex endodontic structures.

Through automated CBCT image interpretation, AI systems are capable of:

- determining the number and configuration of root canals;
- detecting fractured endodontic instruments;
- assessing root perforations; and
- evaluating the quality of root canal obturation.

Several studies have reported diagnostic accuracies exceeding **95%** for the detection of periapical lesions using AI-assisted analysis. These findings indicate the potential of artificial intelligence to improve diagnostic precision and support clinical decision-making in endodontic treatment.

Artificial Intelligence in Implantology. In implant dentistry, artificial intelligence technologies provide valuable support during treatment planning by enabling precise analysis of anatomical structures and optimization of surgical procedures. AI-based systems are capable of:

- assessing available bone volume;
- calculating bone density;
- identifying the location of the mandibular canal;
- automatically defining the boundaries of the maxillary sinus; and
- recommending optimal implant length and diameter.

The integration of AI into implant planning improves surgical safety, enhances treatment predictability, and reduces operative time. By providing accurate three-dimensional anatomical assessments, AI contributes to more individualized and reliable implant placement strategies.

Artificial Intelligence in Orthodontics. In orthodontics, artificial intelligence is applied for:

- automatic identification of cephalometric landmarks;
- analysis of tooth position and alignment;
- simulation of treatment outcomes; and

- prediction of aligner movement.

The implementation of AI significantly reduces analysis time and improves the reproducibility and reliability of orthodontic measurements. These capabilities enhance treatment planning efficiency and support more individualized orthodontic approaches.

Artificial Intelligence in Prosthodontics. When integrated with CAD/CAM systems, artificial intelligence provides advanced capabilities in prosthodontic workflows, including:

- processing of digital impressions;
- analysis of occlusal relationships; and
- automated optimization of the design of crowns, fixed dental prostheses, and veneers.

The use of AI in prosthodontics improves the accuracy of digital restorations and contributes to higher levels of both functional and aesthetic patient satisfaction.

Table 1 – Applications of Artificial Intelligence in Dentistry Based on Khanagar et al. (2021)

Dental Specialty	AI Application	Main Purpose	Main Advantage
Restorative dentistry	Dental caries detection	Detection and diagnosis of dental caries	Early and automated diagnosis
Periodontology	Periodontal disease assessment	Analysis and diagnosis of periodontal conditions	Improved diagnostic support
Endodontics	Root canal analysis	Identification and assessment of root canal anatomy	Reduction of diagnostic errors
Orthodontics	Cephalometric analysis	Automated analysis of cephalometric images	Reduced analysis time
Prosthodontics	Treatment planning and restoration design	Support for prosthetic treatment planning	Improved accuracy and efficiency
Oral and maxillofacial radiology	Dental image analysis	Detection and classification of abnormalities	Faster and more objective image interpretation
Oral medicine / pathology	Oral disease detection	Identification of pathological changes	Earlier detection and clinical decision support

Source: Compiled by the authors based on Khanagar SB, Al-Ehaideb A, Maganur PC, et al. *Developments, application, and performance of artificial intelligence in dentistry – A systematic review*. Journal of Dental Sciences. 2021;16(1):508–522. DOI: 10.1016/j.jds.2020.06.019. [PubMed / Full Text — Khanagar et al. \(2021\)](#)

Table 2 – Applications and Diagnostic Capabilities of Artificial Intelligence in Dentistry Based on Khanagar et al. (2021)

Dental Application Area	AI Application	Diagnostic / Clinical Purpose	Main Benefit
Dental caries	AI-based caries detection	Detection and diagnosis of dental caries from dental images	Early and automated detection

Periodontal diseases	AI-assisted periodontal assessment	Identification and assessment of periodontal conditions	Improved diagnostic support
Endodontics	AI-assisted endodontic diagnosis	Analysis of root canal anatomy and endodontic conditions	Reduction of diagnostic errors
Orthodontics	Automated cephalometric analysis	Identification and analysis of cephalometric landmarks	Faster analysis and treatment planning
Oral cancer and oral diseases	AI-based image analysis	Detection and classification of pathological changes	Earlier detection and clinical decision support
Dental radiology	Automated dental image interpretation	Detection and classification of dental abnormalities	Faster and more objective image analysis
Prosthodontics	AI-assisted treatment planning	Support for prosthetic diagnosis and treatment planning	Improved efficiency and treatment planning
Dental implantology	AI-assisted implant planning	Support for implant-related diagnosis and treatment planning	Improved planning and clinical decision-making

Source: Compiled by the authors based exclusively on Khanagar SB, Al-Ehaideb A, Maganur PC, et al. *Developments, application, and performance of artificial intelligence in dentistry – A systematic review*. Journal of Dental Sciences. 2021;16(1):508–522. DOI: 10.1016/j.jds.2020.06.019.

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Overall, the conducted analysis demonstrates that artificial intelligence is evolving in dentistry beyond a diagnostic tool and is becoming an intelligent clinical decision-support system. Continuous improvement of AI algorithms contributes to enhanced clinical performance, improved treatment planning, and the transition of digital dentistry toward a new stage of technological development.

Discussion. The results of this literature review demonstrate that artificial intelligence (AI) is being actively integrated into all major fields of modern dentistry and is becoming an increasingly important component of clinical practice. In recent years, the rapid development of machine learning (ML) and deep learning (DL) technologies has significantly improved the accuracy of dental disease diagnosis, treatment planning, and clinical decision-making processes.

According to the findings of this review, one of the most significant achievements of artificial intelligence is the improvement of diagnostic accuracy. While conventional diagnosis largely depends on the clinician's professional experience, clinical reasoning, and ability to interpret medical images, AI algorithms are capable of analyzing thousands of images within seconds and identifying subtle pathological changes that may be difficult for the human eye to detect. This advantage is particularly important for the early detection of dental caries, periapical inflammatory lesions, initial bone resorption, and complex root canal anatomy. Several international studies have demonstrated that convolutional neural networks (CNNs) can achieve

diagnostic sensitivity and specificity comparable to or even exceeding those of experienced dental professionals. These findings confirm the potential of AI as an effective clinical decision-support tool. However, the current scientific consensus considers artificial intelligence not as a replacement for clinicians, but as an intelligent technology designed to complement and enhance professional expertise.

The findings of this review are consistent with publications by Schwendicke and colleagues, Khanagar and co-authors, Hung and other researchers. These studies have demonstrated the high accuracy of AI applications in radiological diagnosis, their ability to reduce diagnostic errors, and their potential to improve clinical workflow efficiency. Furthermore, many authors emphasize that the integration of AI into clinical practice not only increases dentists' productivity but also improves the overall quality of patient care. In periodontology, studies have demonstrated the effectiveness of AI-based systems for automated assessment of alveolar bone levels. Previously, such measurements depended largely on manual evaluation by clinicians, whereas modern intelligent algorithms can provide objective and quantitative assessment of periodontal bone loss. This capability allows more accurate monitoring of disease progression, evaluation of treatment effectiveness, and prediction of long-term clinical outcomes.

The role of artificial intelligence in endodontics is also of particular importance. Numerous studies have shown the high efficiency of AI in detecting additional root canals, evaluating periapical changes, and monitoring the quality of endodontic treatment. Automated analysis of cone-beam computed tomography (CBCT) images facilitates the diagnosis of complex clinical cases and improves treatment planning. Consequently, AI-assisted approaches may reduce the need for retreatment and contribute to improved long-term clinical outcomes.

Significant progress has also been observed in implantology. Modern AI-based software systems are capable of automatically analyzing bone volume, mineral density, and the location of critical anatomical structures to determine the optimal implant position. These technologies enhance surgical safety, reduce operative time, and minimize the risk of complications. Additionally, the use of AI-supported surgical guides improves implant placement accuracy and predictability.

In orthodontics, the implementation of artificial intelligence has considerably simplified the diagnostic process. Automated cephalometric analysis, prediction of tooth movement, and simulation of aligner treatment effects reduce clinicians' workload and improve the precision of treatment planning. These advantages are particularly valuable in complex orthodontic cases where accurate clinical decision-making is essential.

Similarly, in prosthodontics, the integration of AI with digital modeling and CAD/CAM technologies enables the production of high-quality dental restorations with improved functional and aesthetic outcomes. AI algorithms can automatically evaluate occlusal relationships, distribution of masticatory forces, and anatomical characteristics. As a result, the accuracy of crowns, fixed dental prostheses, and other restorations is improved, while the need for clinical adjustments is reduced.

Despite these advantages, several challenges continue to limit the widespread implementation of artificial intelligence in dentistry. One of the major limitations is the dependence of algorithm performance on the quality and diversity of training datasets. If a neural network is trained using images obtained from a specific geographic region or a single healthcare

institution, its diagnostic accuracy may decrease when applied to different populations. Therefore, the development of large-scale, multicenter international databases remains an important priority.

Another critical issue is the protection and security of medical information. AI systems require large volumes of medical images and patient-related clinical data for training and validation. Therefore, ensuring data privacy, cybersecurity, and compliance with international ethical standards represents one of the fundamental requirements of modern digital healthcare.

Ethical considerations also require careful attention. In cases where an AI system produces an incorrect diagnosis, the question of responsibility remains insufficiently defined. Current legal frameworks in many countries do not yet provide clear regulations regarding liability in such situations. Therefore, international organizations emphasize the need to establish unified legal and ethical standards for the safe and responsible use of artificial intelligence in healthcare.

In the Republic of Kazakhstan, the digital transformation of healthcare represents one of the important directions of national health policy. In recent years, digital health platforms, electronic medical records, and telemedicine systems have been actively implemented. These developments create favorable conditions for the introduction of AI technologies into dentistry. However, several barriers remain, including limited availability of national clinical databases, high costs of specialized software, and differences in digital competencies among healthcare professionals.

In the coming years, the development of artificial intelligence in dentistry will be closely associated with emerging technologies such as generative artificial intelligence (Generative AI), large language models (Large Language Models), explainable artificial intelligence (Explainable AI), federated learning, and digital twin technologies. These innovations have the potential not only to further improve diagnostic accuracy but also to enable prediction of individualized clinical scenarios, simulation of treatment outcomes, and development of fully personalized dental care approaches.

Overall, the findings of this review indicate that artificial intelligence is becoming an integral component of modern dentistry. Its effectiveness is demonstrated by improved diagnostic accuracy, accelerated clinical decision-making, and enhanced treatment outcomes. However, successful large-scale implementation requires further development of international standards, expansion of clinical research, protection of medical data security, and improvement of digital competencies among dental professionals.

Conclusion. The conducted literature review demonstrated that artificial intelligence technologies are being increasingly integrated into clinical practice in modern dentistry and significantly contribute to improving the efficiency of diagnostic and therapeutic processes. Machine learning and deep learning algorithms have shown high effectiveness in automated analysis of dental images, early detection of pathological changes, prediction of treatment outcomes, and support of clinical decision-making.

The analysis revealed that the highest performance of artificial intelligence has been observed in the diagnosis of dental caries, periapical pathologies, periodontal diseases, implant treatment planning, orthodontic assessment, and the design of prosthodontic restorations. In many clinical applications, the diagnostic accuracy of modern AI algorithms has reached levels comparable to those achieved by experienced dental professionals.

Furthermore, artificial intelligence optimizes clinicians' workflow, reduces diagnostic errors, enables personalized treatment planning, and improves the overall quality of patient care. Particularly in the context of digital dentistry development, the integration of AI with cone-beam computed tomography (CBCT), digital radiography, CAD/CAM technologies, and intraoral scanning systems is creating new opportunities for advancing clinical practice.

Despite these advantages, the widespread implementation of artificial intelligence requires addressing several important challenges. These include the development of unified international standards, ensuring medical data security, improving algorithm reliability across diverse populations, strengthening legal and ethical regulations, and enhancing digital competencies among dental professionals.

In the Republic of Kazakhstan, the ongoing digital transformation of the healthcare system provides favorable conditions for the adoption of artificial intelligence technologies in dentistry. In the future, the development of national clinical databases, expansion of international scientific collaboration, and implementation of clinically validated intelligent systems may significantly improve the quality of dental care.

In conclusion, artificial intelligence should not be considered a replacement for dental professionals but rather an advanced clinical decision-support tool that enhances diagnostic accuracy and contributes to the improvement of evidence-based dental care. Further development of AI technologies will play an important role in establishing patient-centered, safe, and personalized approaches to dental treatment.

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SIGNIFICANCE OF FLUOROGRAPHY IN PREVENTIVE EXAMINATION OF CITIZENS

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Abstract. The frequency of undergoing screening fluorographic examinations depends on age, employment status, and education level; therefore, these factors should be considered when planning screening programs and increasing regular and active participation of the population.

The relevance of this study stems from the continuing high epidemiological significance of tuberculosis and the key role of fluorographic examinations in its early detection. Failure to comply with the prescribed fluorographic screening schedules leads to late diagnosis, the development of severe and destructive forms of tuberculosis, and an increased epidemiological risk to the population. Therefore, studying the factors influencing the regularity of screening fluorographic examinations is of great practical importance for improving preventive measures and public health education.

Purpose. The aim of the study was to identify factors influencing the regularity of screening fluorography and to identify the subjective reasons for delays.

Materials and methods. The study examined 728 individuals, including 342 patients with newly diagnosed pulmonary tuberculosis and 386 conditionally healthy individuals. It has been established that irregular fluorography screening is more common among unemployed individuals of working age and those with low levels of education. Increasing the interval between screenings by more than one year significantly increases the risk of developing tuberculosis, and exceeding two years doubles the risk. Data were collected and analyzed using a standardized questionnaire and medical records. The timing of screening fluorography examinations, as well as to determine the relative risk of developing pulmonary tuberculosis when screening schedules are not met.

Conclusion. Fluorographic screening adherence was associated with age, employment status, and educational level. Screening delays of more than one year significantly increased the risk of pulmonary tuberculosis, while delays exceeding two years doubled the risk. Enhanced monitoring and targeted interventions are needed for high-risk groups.

Keywords: pulmonary tuberculosis, fluorography, screening, pathology, statistics, epidemic, prevention, diagnostics.

АЗАМАТТАРҒА ПРОФИЛАКТИКАЛЫҚ ТЕКСЕРІС ЖҮРГІЗУДЕГІ ФЛЮОРОГРАФИЯНЫҢ МАҢЫЗЫ

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Аңдатпа. Скринингтік флюорографиялық тексерулердің жиілігі жасқа, жұмыспен қамтылуға және білім деңгейіне байланысты болғандықтан, бұл ерекшеліктерді скринингті жоспарлау мен халықтың тұрақты және белсенді қатысуын арттыру болып саналады. Бұл зерттеудің өзектілігі туберкулездің жоғары эпидемиологиялық маңыздылығының сақталуынан және флюорографиялық тексерулердің оны ерте анықтаудағы негізгі рөлінен туындайды. Белгіленген флюорографиялық скрининг кестелерін сақтамау кеш диагноз қоюға, туберкулездің ауыр және деструктивті түрлерінің дамуына және халық үшін эпидемиологиялық қауіптің жоғарылауына әкеледі. Сондықтан, скринингтік флюорографиялық тексерулердің тұрақтылығына әсер ететін факторларды зерттеу алдын алу шараларын және қоғамдық денсаулық сақтау саласындағы білім беруді жақсарту үшін өте маңызды практикалық маңызға ие.

Мақсаты. Зерттеудің мақсаты скринингтік флюорографияның тұрақтылығына әсер ететін факторларды анықтау және кешігулердің субъективті себептерін анықтау болды.

Материалдар мен әдістер. Зерттеуде 728 адам, оның ішінде жаңадан анықталған өкпе туберкулезімен ауыратын 342 науқас және шартты түрде сау 386 адам тексерілді. Тұрақты емес флюорографиялық тексеру жұмыссыз және білім деңгейі төмен адамдар арасында жиі кездесетіні анықталды. Скринингтер арасындағы аралықты бір жылдан астамға ұзарту туберкулездің даму қаупін айтарлықтай арттырады, ал екі жылдан асып кету қауіпті екі есеге арттырады. Деректерді статистикалық өңдеу бізге жастың, білім деңгейінің, әлеуметтік мәртебенің және жұмыспен қамтудың флюорографиялық тексерулердің тұрақтылығына әсерін бағалауға, сондай-ақ скринингтік кестелер орындалмаған кезде өкпе туберкулезінің даму қаупін анықтауға мүмкіндік берді.

Қорытынды. Скринингтік флюорографиялық тексерулердің тұрақтылығы жасқа, жұмыспен қамтылуға және білім деңгейіне байланысты болды. Флюорографияның бір жылдан астам кешіктірілуі өкпе туберкулезінің даму қаупін арттырса, екі жылдан асуы қауіпті екі есеге жоғарылатты. Бұл жоғары қауіпті топтарда скринингті бақылауды күшейту қажеттігін көрсетеді.

Түйін сөздер: өкпе туберкулезі, флюорография, скрининг, патология, статистика, эпидемия, профилактика, диагностика.

ЗНАЧЕНИЕ ФЛЮОРОГРАФИИ В ПРОФИЛАКТИЧЕСКОМ ОСМОТРЕ ГРАЖДАН

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Аннотация. Регулярность прохождения скрининговых флюорографических обследований зависит от возраста, занятости и уровня образования, поэтому эти факторы необходимо учитывать при планировании скрининга и повышении регулярного и активного участия населения. Актуальность исследования обусловлена сохраняющейся высокой эпидемиологической значимостью туберкулёза и ведущей ролью флюорографического обследования в его раннем выявлении. Нарушение регламентированных сроков прохождения флюорографии приводит к поздней диагностике заболевания, формированию тяжёлых и деструктивных форм туберкулёза и повышению эпидемиологической опасности для населения. В этой связи изучение факторов, влияющих на регулярность прохождения проверочного флюорографического обследования, имеет важное практическое значение для совершенствования профилактических мероприятий и санитарно-просветительной работы.

Цель. Цель исследования - определить факторы, влияющие на регулярность прохождения населением проверочного ФЛГО и вскрыть субъективные причины, приводящие к нарушению его сроков.

Материалы и методы. В ходе исследования было обследовано 728 человек, из которых 342 пациента с впервые выявленным туберкулёзом лёгких и 386 условно здоровых лиц. Установлено, что нерегулярное прохождение флюорографического обследования чаще отмечается среди неработающих лиц трудоспособного возраста и лиц с низким уровнем образования. При увеличении интервала между обследованиями более чем на один год отмечается достоверный рост риска развития туберкулёза, а при превышении двухлетнего интервала риск возрастает в два раза. Статистическая обработка данных позволила оценить влияние возраста, уровня образования, социальной принадлежности и занятости на регулярность прохождения флюорографии, а также определить относительный риск развития туберкулёза лёгких при нарушении регламентированных сроков обследования.

Вывод. Высокая эпидемиологическая значимость туберкулёза и ключевая роль флюорографии в его раннем выявлении определяют необходимость соблюдения сроков проверочного обследования. Их нарушение способствует поздней диагностике и повышает риск развития тяжёлых форм заболевания, что требует изучения факторов, влияющих на регулярность прохождения флюорографии.

Ключевые слова: туберкулез легких, флюорография, скрининг, патология, статистика, эпидемия, профилактика, диагностика.

Introduction. Respiratory tuberculosis remains a pressing medical and social health problem due to its severe course, high disability rates, and persistent epidemiological significance. Despite improvements in diagnostic and treatment methods, the timely detection of tuberculosis is largely determined by the effectiveness of preventive screening of the population.

In the Republic of Kazakhstan, the primary method for mass detection of tuberculosis in adults remains screening fluorography, which allows for the diagnosis of pathological changes in the respiratory system in the early stages of the disease. However, the diagnostic value of this method directly depends on its regularity. Failure to comply with the prescribed fluorography schedule leads to late detection of tuberculosis, the development of widespread and destructive forms of the disease, and an increased risk of bacterial excretion and further spread of infection.

According to scientific research, a significant proportion of patients with newly diagnosed respiratory tuberculosis have not undergone fluorographic screening for two or more years, indicating a lack of adherence to preventive screening. Therefore, studying the factors and subjective factors influencing the regularity of screening fluorographic screening, as well as assessing their role in determining individual risk of developing tuberculosis, is particularly relevant.

A comprehensive analysis of the socio-demographic characteristics, education level, and employment status of the population allows us to justify the need for a differentiated approach to public health education and the development of effective preventive measures aimed at increasing the coverage of regular fluorographic screening.

Materials and Methods. The study sample included newly diagnosed patients with pulmonary tuberculosis undergoing inpatient treatment at the Regional Tuberculosis Dispensary (342 individuals, including 229 from the outpatient risk group, i.e., those with diabetes, chronic non-specific lung diseases, peptic ulcers, HIV infection, and those receiving long-term corticosteroids) and healthy individuals living in Shymkent and the Turkestan region (386 individuals, including 137 from the outpatient risk group). The study was conducted using a specially developed questionnaire that included data on age, gender, social status, educational level, and the timing of the screening.

FLOG screening was performed: for patients with tuberculosis, the screening period was prior to the diagnosis of the disease, and for healthy individuals, the screening period was prior. Individuals who underwent screening fluorographic examination within the prescribed timeframes constituted Group I (497 people), while those who violated them constituted Group II (231 people).

Depending on these terms, tuberculosis patients and healthy individuals were divided into two groups. Group 1 (those observing the regulated terms of the verification fluorographic examination) included individuals from the outpatient risk group (tuberculosis patients and healthy individuals), with the term of the last fluorographic examination not exceeding 1 year, as well as individuals without a risk group disease (tuberculosis patients and healthy individuals), with the term of the last fluorographic examination not exceeding 2 years; a total of 497 individuals were included in this group. Group 2 (those violating the regulated terms of the verification fluorographic examination) included individuals from the outpatient risk group (tuberculosis patients and healthy individuals), with the term of the last fluorographic

examination exceeding 1 year, as well as individuals without a risk group disease (tuberculosis patients and healthy individuals), with the term of the last fluorographic examination over 2 years; a total of 231 individuals were included in this group. The Shapiro-Wilk criterion was used to determine whether the terms of the verification fluorographic examination obey the law of normal distribution. At the significance level (p) less than 0.05, the hypothesis of normal distribution was rejected. Since the data did not obey the law of normal distribution, they were presented as the median and 95% CI (Me [L; U], where L is the lower limit of CI, U is the upper limit of CI). For proportions, 95% CI was calculated using the Wald-Wolfowitz method. The statistical significance of differences in quantitative indicators was determined using the Mann-Whitney test. Differences between qualitative (nominal) features were assessed using the χ^2 criterion (the results are presented as: χ^2 is the criterion value, df is the number of degrees of freedom, p is the significance level). To assess the impact of violation of the terms of screening fluorographic examination of the population on the individual risk of developing pulmonary tuberculosis, the relative risk indicator - RR (presented as: RR and 95% CI) was calculated. The null hypothesis of no statistically significant differences was rejected at $p < 0.05$.

Age Structure of Individuals.

Table 1. Complying with and Violating the Timing of Preventive Fluorographic Examination (absolute numbers, %, $\pm 95\%$ CI)

Age group	1st group	2nd group
18-19 years old	25 80,6 $\pm$ 13,92	6 19,4 $\pm$ 13,92
20-29 years old	102 65,4 $\pm$ 7,46	54 34,6 $\pm$ 7,46
30-39 years old	120 69,4 $\pm$ 6,87	53 30,6 $\pm$ 6,87
40-49 years old	73 55,3 $\pm$ 8,48	59 44,7 $\pm$ 8,48
50-59 years old	84 67,7 $\pm$ 8,23	40 32,3 $\pm$ 8,23
60-69 years old	46 76,7 $\pm$ 10,69	14 23,3 $\pm$ 10,69
More than 70 years	47 90,4 $\pm$ 8,01	5 9,6 $\pm$ 8,01

The proportion of individuals violating the timing of preventive fluorographic examination did not differ significantly between rural and urban residents (30.5 $\pm$ 4.1% versus 34.3 $\pm$ 5.8%, respectively; $p = 0.277$).

In the age structure, however, statistically significant differences were identified ($\chi^2 = 30.520$; df = 6; $p < 0.001$). Thus, in the age groups of 20–29 years, 60–69 years, and over 70 years, the proportion of individuals in Group I was the highest. The maximum proportion of individuals in Group II was observed in the 40–49-year age group,

which was associated with the highest level of employment activity in this age category ($38.6 \pm 8.3\%$).

Table 2. Social Structure of Individuals

Complying with and Violating the Timing of Preventive Fluorographic Examination (absolute numbers, %, $\pm 95\%$ CI)

Social group	1st group	2nd group
Workers	95 66.0 ± 7.73	49 34.0 ± 7.73
Officers	93 75.0 ± 7.62	31 25.0 ± 7.62
Pensioners	94 79.0 ± 7.31	25 21.0 ± 7.31
Disabled	31 73.8 ± 13.29	11 26.2 ± 13.29
Not working, of working age	142 56.8 ± 6.14	108 43.2 ± 6.14
Other categories*	42 73.1 ± 12.4	7 26.9 ± 12.4

As follows from the data presented in Table 2, individuals of working age most frequently violated the established timing of preventive fluorographic examination ($43.2 \pm 6.1\%$).

Among working professions, every third individual violated the examination schedule, while among students such violations were recorded only in isolated cases. Among pensioners, the proportion of individuals violating the timing of preventive fluorographic examination was $21.0 \pm 7.3\%$, which is likely due to the fact that pensioners traditionally demonstrate the highest activity in terms of systematic participation in preventive medical examinations.

It should be noted that $45.1 \pm 5.0\%$ of individuals included in Group II who belonged to the clinical risk group for tuberculosis did not undergo preventive fluorographic examination for more than one year.

In this case, responsibility for irregular performance of preventive fluorographic examination lies entirely with the medical personnel of the assigned healthcare network. According to the survey conducted, it was found that one of the main reasons for violation of the timing of preventive fluorographic examination was careless attitude toward one's own health ($39.0 \pm 6.29\%$). In second place was lack of time ($35.9 \pm 6.18\%$), and in third place — self-confidence ($24.7 \pm 5.56\%$).

The inability to undergo preventive fluorographic examination due to limited access was indicated only in isolated cases ($0.4 \pm 0.81\%$).

The need to optimize working conditions and the introduction of home-based examination services, as well as insufficient awareness and low value placed on personal health, are barriers to timely access to medical care.

The risk of developing tuberculosis among individuals who did not undergo preventive fluorographic examination for more than one year was more than 1.5 times higher than among those who were examined regularly.

Table 3. Educational Level of Individuals

Complying with and Violating the Timing of Preventive Fluorographic Examination (absolute numbers, %, $\pm$ 95% CI)

Educational Level	1st group (n=497)	2nd group (n=231)
Basic general	65 62.5 $\pm$ 9.30	39 37.5 $\pm$ 9.30
Secondary	103 62.8 $\pm$ 7.39	61 37.2 $\pm$ 7.39
Secondary vocational	85 64.9 $\pm$ 8.17	46 35.1 $\pm$ 8.17
Secondary special	106 67.9 $\pm$ 7.32	50 32.1 $\pm$ 7.32
Incomplete higher and higher	138 79.8 $\pm$ 5.98	35 20.2 $\pm$ 5.98

The structure of the educational level of individuals included in Groups I and II is presented in Table 3 ($\chi^2 = 16.055$; $df = 5$; $p = 0.007$). As follows from the data presented in Table 3, adherence to the established timing of preventive fluorographic examination depends on the level of education. Thus, individuals with basic general education violated examination timing in 37.5 $\pm$ 9.30% of cases, whereas among those with secondary specialized education this figure was 35.1 $\pm$ 8.17%, and among individuals with higher and incomplete higher education — only 20.2 $\pm$ 5.98%. The risk of developing pulmonary tuberculosis in individuals who have not undergone screening fluorographic examination for more than one year is more than 1.5 times higher than in individuals who undergo it every year (RR=1.8 [1.50; 2.06]), and in those who have not undergone it for more than two years, the risk is already more than 2 times higher (RR=2.1 [1.83; 2.39]).

In individuals who have not undergone screening fluorographic examination for more than three, four and five years, the risk of developing pulmonary tuberculosis (respectively RR=2.1 [1.87; 2.40]; RR=2.0 [1.77; 2.29] and RR=2.0 [1.81; 2.32]) did not differ significantly from that in those who have not undergone this examination for more than two years. Therefore, when planning and conducting screening FLGO, special attention should be paid to this category of the population. Thus, the factors influencing the regularity of FLGO screening by the population include age, unemployment, and education level. The highest proportion of individuals who comply with the regulated FLGO screening period is among pensioners and

individuals with incomplete higher education, while those who do not comply are unemployed individuals of working age. According to the survey results, the reasons for irregular FLGO screening were a careless attitude towards one's health, being busy at work, and overconfidence.

The risk of developing tuberculosis in individuals who have not undergone FLGO screening for more than one year is more than 1.5 times higher than in those who undergo it annually; extending the FLGO screening period by more than two years doubles the risk of developing tuberculosis. These data should be taken into account when conducting public health education campaigns to motivate the population to regularly undergo FLGO screening.

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WORKPLACE STRESS AND BURNOUT AMONG EMPLOYEES IN HIGH-TECHNOLOGY AND RESEARCH INSTITUTIONS: A REVIEW OF NURSING ROLES AND INTERVENTIONS

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Abstract. Stress and burnout have become significant issues in high-tech and research institutions, particularly for employees in demanding environments. This systematic review examines the causes, consequences, and nursing interventions for workplace stress and burnout. Utilizing peer-reviewed articles from PubMed, Scopus, and Google Scholar, with keywords like "workplace stress," "burnout," and "nursing interventions," the review highlights organizational, environmental, and psychological stressors as primary contributors to burnout. Nursing professionals play a crucial role in offering stress management interventions, including mindfulness-based stress reduction (MBSR), cognitive behavioral therapy (CBT), and peer support networks, which can alleviate emotional exhaustion and improve job satisfaction. The review also identifies barriers to the implementation of these interventions, such as organizational constraints, workforce adaptation challenges, and ethical considerations related to AI in nursing practice. Despite these challenges, the study emphasizes the importance of training nurses in AI, designing nursing-specific tools, and fostering organizational support to reduce stress and burnout. Recommendations for improving nursing interventions and enhancing overall well-being in high-tech and research settings are provided.

Keywords: Workplace Stress, Burnout, Nursing Interventions, High-Tech Institutions, Mindfulness-Based Stress Reduction.

ЖОҒАРЫ ТЕХНОЛОГИЯЛЫҚ ЖӘНЕ ҒЫЛЫМИ-ЗЕРТТЕУ МЕКЕМЕЛЕРІ ҚЫЗМЕТКЕРЛЕРІ АРАСЫНДАҒЫ ЖҰМЫС ОРНЫНДАҒЫ СТРЕСС ПЕН ЭМОЦИЯЛЫҚ КҮЙШІ КЕТУ: МЕЙІРГЕРЛІК ҚЫЗМЕТТІҢ РӨЛІ МЕН АРАЛАСУЛАРЫНА ШОЛУ

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Аңдатпа. Жұмыс орнындағы стресс пен эмоциялық күйіп кету жоғары технологиялық және ғылыми-зерттеу мекемелерінде, әсіресе еңбек жүктемесі жоғары қызметкерлер арасында маңызды мәселеге айналды. Бұл жүйелі шолу жұмыс орнындағы стресс пен эмоциялық күйіп кетудің себептерін, салдарын және олардың алдын алу мен төмендетуге бағытталған мейіргерлік араласуларды қарастырады. Талдау PubMed, Scopus және Google Scholar дереккөздерінен «жұмыс орнындағы стресс», «эмоциялық күйіп кету» және «мейіргерлік араласулар» кілт сөздері бойынша іріктелген рецензияланған ғылыми мақалаларға негізделген. Шолу нәтижелері ұйымдық, өндірістік және психологиялық стресс факторлары эмоциялық күйіп кетудің негізгі себептері екенін көрсетті. Мейіргерлер стрессті басқаруға бағытталған араласуларды жүзеге асыруда маңызды рөл атқарады. Олардың қатарына саналылыққа негізделген стрессті төмендету бағдарламалары (Mindfulness-Based Stress Reduction, MBSR), когнитивті-мінез-құлықтық терапия (CBT) және әріптестік қолдау желілерін ұйымдастыру жатады. Бұл шаралар эмоциялық сарқылуды азайтып, қызметкерлердің жұмысқа қанағаттануын арттыруға ықпал етеді. Сонымен қатар, шолуда мұндай араласуларды енгізуге кедергі келтіретін факторлар анықталды. Оларға ұйымдық шектеулер, қызметкерлердің жаңа тәсілдерге бейімделуіндегі қиындықтар және мейіргерлік тәжірибеде жасанды интеллектіні қолдануға байланысты этикалық мәселелер жатады. Осы қиындықтарға қарамастан, зерттеу мейіргерлерді жасанды интеллект технологияларын қолдануға оқытудың, мейіргерлік тәжірибеге арналған арнайы құралдарды әзірлеудің және ұйымдық қолдауды күшейтудің маңыздылығын атап көрсетеді. Сонымен қатар, жоғары технологиялық және ғылыми-зерттеу мекемелерінде қызметкерлердің әл-ауқатын жақсарту мен стресс және эмоциялық күйіп кету деңгейін төмендетуге бағытталған ұсыныстар берілген.

Түйін сөздер: жұмыс орнындағы стресс, эмоциялық күйіп кету, мейіргерлік араласулар, жоғары технологиялық мекемелер, саналылыққа негізделген стрессті төмендету бағдарламасы (MBSR).

СТРЕСС НА РАБОЧЕМ МЕСТЕ И ЭМОЦИОНАЛЬНОЕ ВЫГОРАНИЕ СРЕДИ СОТРУДНИКОВ ВЫСОКОТЕХНОЛОГИЧНЫХ И НАУЧНО-ИССЛЕДОВАТЕЛЬСКИХ УЧРЕЖДЕНИЙ: ОБЗОР РОЛИ МЕДИЦИНСКИХ СЕСТЕР И ИХ ВМЕШАТЕЛЬСТВ

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Аннотация. Стресс и эмоциональное выгорание стали серьезными проблемами в высокотехнологичных и научно-исследовательских учреждениях, особенно среди сотрудников, работающих в условиях высокой профессиональной нагрузки. В данном систематическом обзоре рассматриваются причины, последствия и сестринские вмешательства, направленные на профилактику и снижение уровня профессионального

стресса и эмоционального выгорания. Анализ основан на рецензируемых публикациях, отобранных из баз данных PubMed, Scopus и Google Scholar с использованием ключевых слов «рабочий стресс», «эмоциональное выгорание» и «сестринские вмешательства». Результаты обзора показывают, что основными факторами, способствующими развитию эмоционального выгорания, являются организационные, производственные и психологические стрессоры. Медицинские сестры играют важную роль в реализации мероприятий по управлению стрессом, включая программы снижения стресса на основе осознанности (Mindfulness-Based Stress Reduction, MBSR), когнитивно-поведенческую терапию (CBT) и создание сетей взаимной поддержки, что способствует уменьшению эмоционального истощения и повышению удовлетворенности трудом. В обзоре также выявлены препятствия для внедрения данных вмешательств, включая организационные ограничения, сложности адаптации персонала и этические вопросы, связанные с применением искусственного интеллекта в сестринской практике. Несмотря на существующие трудности, исследование подчеркивает важность обучения медицинских сестер использованию технологий искусственного интеллекта, разработки специализированных инструментов для сестринской практики и укрепления организационной поддержки с целью снижения уровня стресса и эмоционального выгорания. Представлены рекомендации по совершенствованию сестринских вмешательств и повышению общего благополучия сотрудников в высокотехнологичных и научно-исследовательских учреждениях.

Ключевые слова: рабочий стресс, эмоциональное выгорание, сестринские вмешательства, высокотехнологичные учреждения, снижение стресса на основе осознанности (MBSR).

Introduction. Stress and burnout in the workplace have emerged to be significant issues in contemporary organisations particularly in high-tech and research institutions where workers are constantly subjected to severe work pressures, innovation pressures, and hard deadlines. The necessity to maintain the productivity, accuracy, and competitiveness may subject workers to unceasing psychological and emotional pressure in such environments (Değer, 2024; Haruna, 2023). Consequently, workplace stress is no longer considered as a transient inconvenience but as an occupational health problem of serious consequences to both the employees and organisations.

A multidimensional phenomenon, burnout is associated with emotional exhaustion, depersonalisation, and diminished personal achievement and is a frequent consequence of untreated and long-term workplace stress (Nawaz et al., 2022; Tang et al., 2025; Gkontelos et al., 2025). This condition not only impacts on the emotional and mental wellbeing of workers but also their motivation, concentration, and performance quality. Burnout may undermine the institutional performance and individual productivity in high-tech and research environments, where mental activity, imagination, and critical thinking are the key factors (Ajayi and Udeh, 2024; Joe et al., 2025). Kumar et al. (2024) also indicate that the physical, emotional, mental, and social burnout-related exhaustion lower the capacity of employees to perform effectively according to the professional expectations.

Workplace stress and burnout are especially relevant to those work environments that are high-pressure like technology-driven organisations, laboratories, and research institutions. These places of work are usually typified by extended working hours, performance appraisals, role ambiguity, excessive workloads, and the need to deliver quick outputs. These pressures often lead to chronic occupational stress, which, without an adequate coping mechanism, develops into burnout (Haruna, 2023; Cakirpaloglu et al., 2024). Jin et al. (2023) also highlight that emotional exhaustion is particularly exacerbated when the work demands are high, and the employees have low control over the work conditions. This renders the matter particularly relevant in the facilities where employees are obliged to work at high rates with a minimum amount of recovery time.

Nursing profession provides a valuable insight into stress and burnout at work since nurses often operate in challenging environments where stress impacts are both tangible and severe. Research has revealed that nurses are especially susceptible to burnout because of workload, emotional stress, role conflict, and the stress that comes with the responsibility of patient care (Kızılkaya, 2024; Wilton et al., 2024; Duasin et al., 2024). Emotional exhaustion, depersonalisation, decreased job satisfaction, lapsed care, and work performance have been associated with burnout amongst nurses (Novianti and Budiyo 2025; Getie et al., 2025; Pakpahan et al., 2026). Their experiences also offer a valuable lesson on the factors and effects of work stress and also the importance of nursing professionals in prevention, support, and intervention efforts in the workplace.

Rising rates of stress and burnout among employees in high-tech and research settings have emerged as a highly significant challenge to the well-being of employees and organisational productivity. These industries require constant innovation, accuracy, and rapidness and frequently do not give workers ample time to rest, recuperate, or emotionally adapt. The longer the occupational pressure, the weaker the workers are to exhaustion, disengagement, and decreased professional performance (Deger, 2024; Ajayi and Udeh, 2024). This is not only harmful to individual health, but also compromises team work, imagination, quality of service, and output at the institution.

The issue is even more pressing in the context of research-related and healthcare-oriented facilities in which stress can have a direct impact on decision-making, healthcare outcomes, and safety. Constant exposure to stressors at work has been linked to emotional exhaustion and decreasing ability to cope, negative emotions, and diminished personal accomplishment in employees, especially nurses and other healthcare workers (Duasin et al., 2024; Grotowska et al., 2025). Failure to intervene effectively on this trend will lead to an increase in absenteeism, low job satisfaction, low performance and poor organisational sustainability in institutions.

The primary goal of this review is to discuss the current information on stress and burnout at the workplace among the employees in high-tech and research institutions. In particular, the review aims at examining the significant causes of stress and burnout at work in such environments and discussing their consequences regarding the health of employees, their performance at work, and the productivity of the institution (Ajayi and Udeh, 2024; Joe et al., 2025).

The purpose of the review is also to evaluate the process of managing stress and burnout at the workplace by nursing professionals. Nursing professionals are uniquely placed in a

position to contribute to employee well-being by providing health education, stress management tools, early signs of burnout, and advocacy of health in the workplace due to their frontline experience in dealing with stress-related outcomes in demanding care settings (Wilton et al., 2024; Novianti and Budiyo, 2025). This role can be understood to create multidisciplinary approaches to stress reduction and better occupational health outcomes.

The paper is an important contribution to the literature since it has tackled the increasing problem of occupational health in industries that are important in the field of innovation, knowledge creation, and service provision. Research and high-tech organizations are very dependent on the intellectual, emotional, and physical strength of employees. The knowledge of the underlying causes and consequences of work stress and burnout is critical in protecting the health of the staff and ensuring they remain productive.

Moreover, the research has useful information in informing the organizational policies and practices. The results may be used to develop health and wellness interventions to create stress and burnout reduction strategies, such as workload management strategies, mental health assistance, staff counseling, and involvement of occupational health professionals in the institutional wellness programs.

The paper also highlights the critical importance of nursing professionals in stress and burnout management in the workplace. Their background in diagnosing the symptoms of burnout in their early stages and offering assistance makes them the major stakeholders in the promotion of healthier workplaces. This study proposes a more comprehensive and unified approach to the issues of stress and burnout in high-demand professional environments by emphasizing their contributions.

Methodology

1. Review Design. The systematic review design is adopted in this review so that there is a complete and systematic review of the available literature. The methodical procedure enables the transparent and clear procedure of identifying, evaluating, and synthesizing the relevant studies referring to stress and burnout in the workplace, especially in the high-tech and research setting, and the role of the nursing professionals in managing the given problems.

2. Literature Search Strategy. A thorough literature review will be carried out in various academic databases to obtain the pertinent literature. The databases that will be used to locate peer-reviewed articles, grey literature, and other pertinent sources will be the following:

PubMed, Scopus, Google Scholar. Specific keywords and Boolean operators will be used in the search to narrow the results:

Keywords: work stress, burnout, nursing interventions, high-tech institutions, research settings, occupational health.

Operators of the Boolean type: AND, OR (e.g., workplace stress AND burnout AND nursing interventions AND high-tech institutions).

These keywords will make sure that the review incorporates the relevant studies addressing not only the causes of stress and burnout but also the role of nursing professionals in solving the problem in the research and high-tech settings.

3. Inclusion and Exclusion Criteria.

Inclusion Criteria:

- Research on stress and burnout in the workplace of a high-tech, research, or healthcare institution.
- Studies concerning nursing interventions and their contribution to stress and burnout management at work.

Research that incorporates systematic reviews, empirical research, case studies, and qualitative research that do not leave insights on the occupational health, burnout, and stress in the identified contexts.

Exclusion Criteria:

- Research that concerns stress and burnout at the workplace in non-high-tech or research workplace settings.

Steven et al. (2016) conducted a study that included articles that did not specifically investigate nursing interventions or burnout as a result of workplace stress.

- Articles in non-English languages (unless a corresponding translation exists).
- Research that does not contain adequate information about the causes and effects of burnout or is beyond the scope of this review.

4. Analysis and Extraction of Data.

A standardized data extraction form will be used to extract data on the selected studies. The major variables to be elicited are:

Obviously, the causes of burnout are job demands, role ambiguity, emotional exhaustion, etc.

Clicking on nursing roles: The role of nursing professionals in managing stress, burnout recognition, and support interventions.

Interventions: Interventions or programs that are applied to address stress and burnout in the workplace, especially interventions that target nursing.

Thematic synthesis will be used to analyze the data in order to identify patterns and shared themes in the studies. This qualitative study will assist in summarizing the key results and outlining the role of nursing professionals in dealing with workplace stress and burnout.

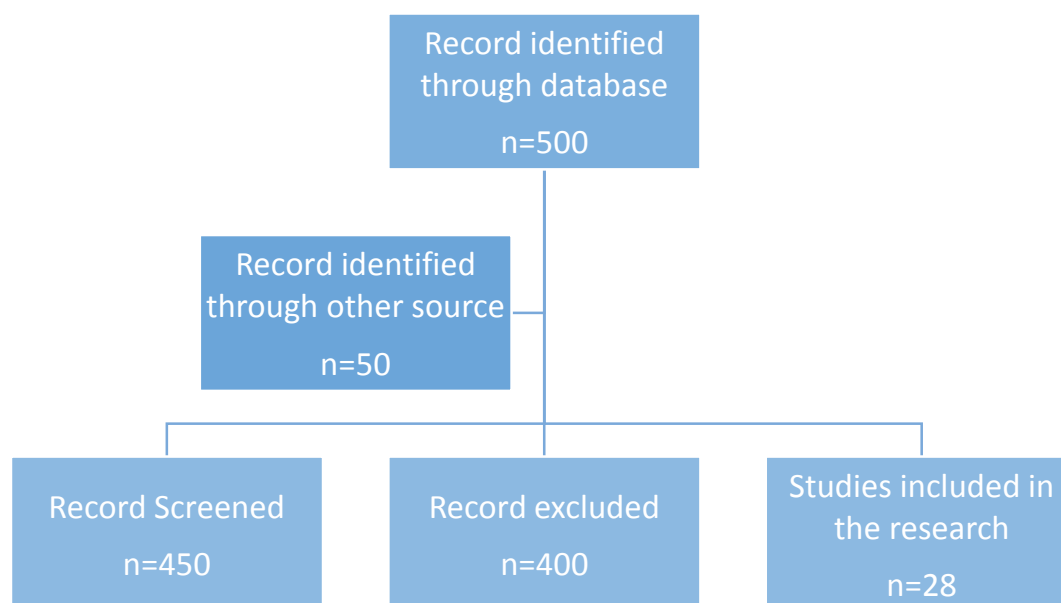


Figure 1. Prisma diagram

3. Stress and Burnout in Workplaces in High-Technology and Research Institutions. High-Tech and Research Institutions Overview.

Technological and research-oriented institutions are characterized by a high-paced, dynamic, and, in many cases, high-pressure environment. The nature of these industries is that the innovation process is always needed; they have to be fast at adapting to new technologies, and they have to be productive and meet deadlines. This brings a professional environment where workers must work at high pressure, and there are high expectations to produce high-quality outputs within a relatively short period of time. In some industries, especially in the information technology, pharmaceutical, engineering, and healthcare areas, the adoption of the emerging technologies and the innovation is a fundamental part of operation in the day-to-day activities. This has resulted in employees in these industries struggling to keep abreast with the technological changes and at the same time manage heavy workloads, the growing complexity of their jobs, and high-stake work responsibilities (Ajayi & Udeh, 2024).

These organizations tend to promote the culture of the always-on, and in this case, the digital aspect of the work environment causes work and personal time to be indistinct. The growing use of digital tools, online teamwork, and remote work only adds to the escalation of work rhythms and longer working hours, which only exacerbates the level of stress and the chance of burnout (Haruna, 2023). The digital technologies that have been introduced in these workplaces have also brought new stressors like technostress, which is the stress that is caused by the excessive use of technology in the workplace. This phenomenon encompasses techno-invasion, whereby work-related technology intrudes into personal life; techno-insecurity, where

employees fear that their technological capabilities are inadequate; and techno-overload, where employees are overwhelmed by information and digital demands (Malik et al., 2025).

Reasons for Workplace Stress and Burnout. High-tech and research institutions are also subject to workplace stress that is caused by various factors, including organizational and environmental stressors and psychological pressure. All these put together have created a situation where burnout is a reality and an increasing problem.

Organizational Stressors: A major stressor in an organization is workload, which is usually aggravated by a set of tight deadlines, high expectations, and job demands, which keep on rising. In the high-tech industry, staff are often expected to balance several duties and assignments, and it is hard to achieve a balance between work and life (Ajayi and Udeh, 2024). Another type of stress is job insecurity, particularly when the organization is undergoing a restructuring or downsizing process, as workers fear the job security within a competitive and rapidly changing industry.

Environmental Stressors: Environmental stressors, including noise in open-plan offices and social isolation in telecommuting settings, are some of the contributors to stress in these settings. This absence of face-to-face contact may cause a sense of disconnection, and strong noise or a disorganized workplace prevents concentration and performance (Hernandez et al., 2022).

Psychological Stressors: Psychological stressors encompass the emotional burden on the employees, especially in the research environment where failure to perform to the expectations can be devastating. Moreover, dissatisfaction with the job (related to the absence of recognition, poor remuneration, and career development opportunities) has also been cited as a major reason causing burnout. There is also a tendency to feel undervalued and overworked, which reduces the motivation and productivity of employees in these high-pressure settings (Kaptanoğlu, 2025).

Effects of Stress and Burnout. Stress and burnout have severe and multi-dimensional impacts on the physical, mental, and emotional condition of employees and the overall performance of the whole organization, which are hard to overlook.

Influence on the Mental and Physical Health of the Employees: Stress and burnout are the causes of various mental health problems such as anxiety, depression, and cognitive fatigue. Physically, workers can have chronic fatigue, headaches, sleeping disorders, and heart problems as the result of continuous exposure to stress. The healthcare industry, specifically, is particularly susceptible because the emotional burden of patient care may result in an increase in cases of stress-related diseases among workers (Kaltenegger et al., 2023).

Effect on Productivity, Innovation, and Job Performance: The productivity is also considerably affected, as employees with burnout usually lose their concentration, become less creative, and lower the quality of work. Innovation is particularly in danger because burnt-out employees might not have the energy and mental clarity that they need to solve problems creatively and engage in constant learning. Job performance is generally reduced, and employees complain of reduced efficiency, increased error rate, and increased absenteeism. Unaddressed burnout may result in higher turnover as well, as employees are trying to get out of the unhealthy atmosphere (Malik et al., 2025; Pinto et al., 2024).

The culture of being always-on and the growing workload with the help of digital technologies also add to the blurring of work-life boundaries, contributing to the technostress

even more. This, in its turn, increases the threat of burnout and adversely influences the well-being of employees and health of the organization.

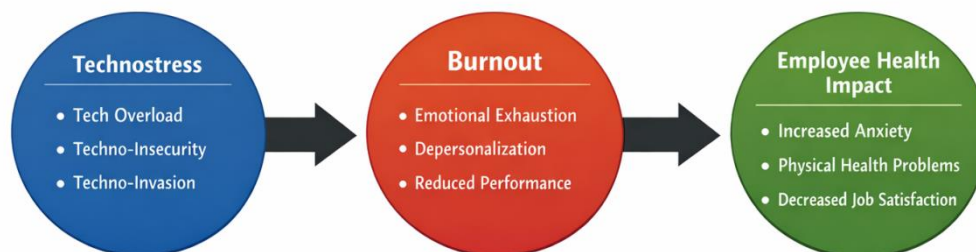


Figure 2: The Relationship Between Technostress, Burnout, and Employee Health

This figure illustrates the progression from technostress to burnout and its subsequent impact on employee health. It highlights how various forms of technostress, such as tech overload, techno-insecurity, and techno-invasion, can trigger emotional exhaustion and depersonalization, which are core components of burnout. As burnout intensifies, it leads to reduced work performance, which, in turn, negatively affects the physical and mental health of employees. The diagram emphasizes the interconnected nature of these stressors and their cumulative effect on an employee's overall well-being, ultimately leading to increased anxiety, physical health issues, and decreased job satisfaction.

4. Nursing Roles in Workplace Stress and Burnout.

High-Tech and Research Institution Nursing Interventions. Nursing professionals are important in solving the problem of stress and burnout in the workplace, especially in the high-tech and research settings where the pressure on employees is usually overwhelming. Nursing interventions are effective concerning stress management and coping mechanisms, which offer both reactive and proactive techniques that enable employees to control the psychological stress. These measures are intended to develop psychological strength and improve coping skills in the challenging settings (Alrehali et al., 2022).

Nursing interventions are applied extensively with the use of individual and group therapies. Nurses usually offer therapeutic care to patients with stress or burnout, employing a method including cognitive behavioral therapy (CBT) and relaxation. These treatments assist the individual to re-appraise their stress reactions, handle their feelings, and alleviate anxiety (Silva et al., 2021). Group therapies, like peer support sessions, help workers to exchange experiences, share feelings, and discuss coping strategies collectively.

Preventative Measures

The preventative measures play a critical role in the reduction of the long-term consequences of workplace stress and burnout. Educational programs, stress relievers, and wellness programs are essential elements of such preventive programs. Stress management workshops, mindfulness training, and physical wellness programs such as yoga are examples of wellness programs that enable employees to stay healthy in physical and psychological conditions (Pasay-an et al., 2025; Yosep et al., 2025).

The stress-reduction programs like frequent breaks, mental health days, and relaxation methods motivate the employees to have a day off from employment in order to refresh and alleviate stress. Educational programs with the purpose of developing sensitivity to stress and burnout and offering means of coping with the conditions are especially significant in work settings with high demands, e.g., high-tech and research facilities. Such programs usually aim at developing adaptive coping and personal awareness, which are critical to long-term resilience at work (Taribuka et al., 2025).



Figure 3: The Role of Nursing Interventions in Mitigating Stress and Burnout

This figure illustrates the interaction between individual-focused nursing interventions and organizational strategies in reducing workplace stress and burnout. It highlights that individual interventions like mindfulness-based stress reduction (MBSR) and cognitive behavioral therapy (CBT), when combined with organizational strategies such as wellness programs and peer support networks, create a comprehensive approach to mitigating stress. The diagram emphasizes the outcomes of these interventions, which include reduced stress, increased job satisfaction, and improved resilience. By showing how both personal and organizational approaches work together, the figure underscores the holistic nature of managing burnout in high-pressure environments like healthcare and research institutions.

Nursing-Specific Approaches

Specific nursing interventions to help fight workplace stress and burnout incorporate mental health nursing models that are customized to tackle the specific issues of the employees in high-stress settings. Mental health nursing models, including those applied in Mindfulness-Based Stress Reduction (MBSR), are specifically useful in assisting employees to cope with emotional fatigue and develop resilience (Poluboiartsev, 2023). This group of models focuses on the current moment, the breathwork, and self-compassion as some of the practices that decrease stress and enhance emotional control (Bhardwaj et al., 2024).

Mindfulness-based interventions have been shown to decrease emotional exhaustion and enhance job satisfaction in nursing personnel in high-stress care settings, including intensive care units (ICUs) (Joe et al., 2025). These methods are not only effective in reducing stress, but they also increase empathy and self-compassion, which are crucial attributes of a nurse who directly treats a patient in a high-pressure environment. Mindfulness-based interventions enable nurses to

acquire adaptive coping skills such as active problem-solving and positive reframing, which are essential in overcoming occupational difficulties (Woods-Giscombé, 2021).

In addition to personal interventions, organizational approaches are also vital in the development of a good workplace. The psychological resilience of nursing professionals is enhanced by the introduction of peer support networks, supportive leadership, and professional development opportunities. These organizational-level measures are in addition to patient interventions, as they create a culture of care and support (Ali & Shaban, 2025; Golparvar & Parsakia, 2023).

Table 1. Nursing Interventions for Stress and Burnout

Intervention Type	Examples	Impact
Mindfulness-Based Stress Reduction	Mindfulness practices, breathwork, body scan exercises	Reduces emotional exhaustion, enhances job satisfaction
Cognitive Behavioural Therapy (CBT)	Reframing negative thoughts, relaxation techniques	Alleviates anxiety, improves emotional regulation
Peer Support Networks	Group therapy, support groups, shared experiences	Increases feelings of support, reduces isolation, fosters resilience
Wellness Programmes	Yoga, stress management workshops, physical activity	Improves physical and mental health, reduces work-related stress
Educational Initiatives	Workshops on stress, burnout prevention training	Increases awareness, promotes self-care, enhances coping skills

5. Measuring the Nursing Intervention Effectiveness.

A Review of the Existing Research on Nursing Interventions. Nursing interventions as a way of dealing with workplace stress and burnout have been a well-researched area with many successful intervention strategies being produced. These interventions are often directed at the individual-level support as well as the systemic changes in the organization. One of the most common practices that have become a major study topic is Mindfulness-Based Stress Reduction (MBSR). It has been demonstrated that MBSR programs can help alleviate emotional exhaustion, anxiety, and burnout as well as enhance job satisfaction and overall well-being in nursing professionals (Poluboiartsev, 2023; Joe et al., 2025). Cognitive behavioral therapy (CBT) and relaxation methods are other intervention options that have shown positive outcomes in alleviating stress and burnout symptoms and enabling nurses to more effectively manage the emotional and psychological stress factors of their jobs (Silva et al., 2021).

Besides interventions based on individuals, peer support groups and group therapies have been identified to work effectively in diminishing the feelings of alienation and giving individuals a sense of belonging and experience. Research has also shown that wellness initiatives, comprising a mix of stress-reducing exercises like yoga and physical activity, help to promote better physical condition, reduce stress, and increase job satisfaction among nursing personnel (Taribuka et al., 2025; Pasay-an et al., 2025).

Although there are positive outcomes related to nursing interventions, there are still difficulties in their implementation, especially in high-tech and research settings, where the adoption of digital technologies and AI is increasingly becoming popular.

Stumbling blocks in the Implementation of Interventions. Nursing interventions are also prone to a number of obstacles, especially in high-tech and research-intensive healthcare ecosystems. Organizational constraints are among the greatest issues, which entail a shortage of funding, time to train the staff, and adequate staff to help implement the interventions. As an example, the implementation of wellness programs or even the introduction of new models of therapeutic interventions, such as MBSR, in resource-limited environments may be obstructed by the shortage of financial and human resources (Shammari et al., 2022, p. 5).

Another challenge is the adaptation of the workforce to new interventions, in particular, to those using digital tools and technologies. Although the introduction of artificial intelligence (AI) into nursing practice is likely to make a major contribution to operational efficiency and clinical results, the change is perceived as a source of resistance among the staff. Numerous nurses lack proper training with the utilization of digital health technologies, and the emergence of AI-driven tools can raise doubts about their functions and tasks (Arab et al., 2025; Maleki et al., 2025).

The other obstacle is the ethical issues of AI implementation in healthcare. Problems like the bias in the algorithms, data privacy, and the possibility of technology misuse are also of concern. These ethical issues may slow down the adoption of AI in the nursing processes and prevent the creation of nursing-specific AI products (Bonfim & Nascimento, 2025; Olorunfemi and Ogwu, 2025). Additionally, AI systems must be strictly tested and validated by longitudinal or experimental research to demonstrate their effectiveness in real life and prevent possible harm to patients (Arab et al., 2025).

Suggestions to Improve the Nursing Roles. To transform these obstacles and increase the efficiency of the nursing interventions, a number of recommendations are offered to enrich nursing positions, especially in the high-tech and research setting:

Integration of AI Training of Nurses: Nursing professionals must have extensive training on how to use digital health technologies, such as AI-based tools, to make sure that they can adjust and use the technologies in an efficient way. It will enable nurses to feel more secure in their duties and minimize opposition to the implementation of new tools (Wei et al., 2025).

Designing Nursing-Specific AI Solutions: The development of AI solutions in specific applications to nursing practices is a critical gap. Healthcare professionals, AI developers, and regulatory bodies should collaborate to develop special and easy-to-use AI tools that meet the needs of nursing staff in a specific manner (Maleki et al., 2025).

Establishing Ethical Rules in the AI Implementation: There should be clear ethical rules that should be put in place to regulate the implementation of AI in nursing practices. These principles must deal with such matters as data privacy, algorithmic transparency, and patient-centered care values, as AI tools are to be employed in an ethical and fair manner (Arab et al., 2025; Hassanein et al., 2025).

Increased Wellness Programs: Wellness programs must be incorporated in the day-to-day activities of the nursing personnel, with special emphasis on stress management, awareness of mental health, and self-care methods. Such programs are to be adjusted to the particular

requirements of nurses operating in high-tech settings, and it can provide a more comprehensive approach to the well-being of employees (Taribuka et al., 2025; Yosep et al., 2025).

Enhancing Organizational Support: Healthcare organizations should focus on the psychological well-being of nursing practitioners by giving them sufficient resources and encouragement. It involves providing time to train, limiting overworking, and creating a positive atmosphere where the nurses will be able to exchange their experiences and seek assistance when necessary (Ali and Shaban, 2025; Golparvar and Parsakia, 2023).

The adoption of peer support systems: The adoption of organized peer support networks can also contribute to lessening isolation and enhancing the overall health of nursing personnel. Such networks can offer nurses a platform to communicate with one another, exchange coping mechanisms, and support each other emotionally (Cohen et al., 2023; Gökçe, 2024).

Through these barriers and the proposed recommendations, the nursing interventions will be better incorporated into the high-tech and research settings. This will not just change the mental and physical status of the nursing professionals but will also increase the outcome of patient care and organizational performance.

Table 2. Key Challenges in Implementing Nursing Interventions

Challenge	Description	Impact on Implementation
Organisational Constraints	Limited funding, lack of personnel, time constraints	Hindrance to effective intervention delivery
Workforce Adaptation	Resistance to new technologies, lack of training	Reduced efficacy of digital tools and new interventions
Ethical Considerations	Algorithmic bias, data privacy issues, misuse of AI tools	Delays in AI adoption, increased resistance, ethical concerns
Lack of Nursing-Specific AI Tools	Limited development of tools tailored to nursing practices	Insufficient support for nursing-specific needs in high-tech settings

Environments. A figure illustrating the interrelationship between training and adaptation, wellness programs, ethical guidelines, and organizational support will provide a visual representation of how these elements work together to improve nursing interventions and overall outcomes in high-tech and research settings.

Conclusion. Workplace stress and burnout in high-tech and research settings involve nursing professionals. Nurses can alleviate the adverse consequences of stress and burnout through specific interventions, such as MBSR, CBT, and peer support groups. Nevertheless, organizational limitations, workforce adjustment, and ethical issues related to the use of AI are only a few challenges that should be overcome to maximize the efficiency of these interventions. Institutions may enhance the well-being of employees and their overall performance by creating nursing-specific AI solutions, growing wellness initiatives, and establishing organizational support.

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CLINICAL AND DIAGNOSTIC EVALUATION OF THE INAPPROPRIATENESS OF CHEST RADIOGRAPHY WITHIN THE FIRST 24 HOURS IN CHILDREN WITH SUSPECTED PNEUMONIA

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Abstract. Pneumonia in children remains one of the most significant problems in modern pediatrics due to its high prevalence and the risk of complications associated with delayed diagnosis. Chest radiography is widely used as a standard imaging method for confirming the diagnosis; however, its use in the early stage of the disease may have limited diagnostic value and contribute to unnecessary radiation exposure.

Classically, four stages of lobar pneumonia are distinguished: congestion, red hepatization, gray hepatization, and resolution. In the early stage (congestion stage), morphological changes in lung tissue are minimal, which limits the diagnostic performance of radiographic imaging.

To evaluate the diagnostic appropriateness of chest radiography performed within the first 24 hours in children with suspected pneumonia and to assess the benefits of delayed imaging in reducing radiation exposure.[1]

The study was conducted at City Polyclinic No. 3 in Shymkent. Radiological data from five children aged 1–3 years with clinically confirmed pneumonia were analyzed. Chest radiography was performed on the first day of illness and repeated on the third day. Additionally, a questionnaire survey of 10 general practitioners was conducted to assess clinical decision-making and awareness of radiation exposure.[2]

On the first day of illness, no radiological abnormalities were detected in 100% of patients despite clinical signs of pneumonia. On the third day, all children (100%) demonstrated radiological features consistent with inflammatory changes in the lungs. Repeated imaging resulted in a twofold increase in cumulative radiation exposure. According to the survey, 70% of physicians prescribe chest radiography within the first day of illness, while only 40% are aware of its limited diagnostic value in early disease stages.

Thus, chest radiography performed within the first 24 hours in children with suspected pneumonia has low diagnostic yield due to minimal morphological changes at the early stage of the disease. Delayed imaging improves diagnostic accuracy and reduces radiation exposure without compromising diagnostic quality.[3]

Keywords: pneumonia, stages of pneumonia, chest radiography, radiation exposure, delayed diagnosis.

**БАЛАЛАРДА ПНЕВМОНИЯҒА КҮДІК КЕЗІНДЕ КЕУДЕ ҚУЫСЫ
АҒЗАЛАРЫНЫҢ РЕНТГЕНОГРАФИЯСЫН АЛҒАШҚЫ ТӘУЛІКТЕ
ЖҮРГІЗУДІҢ ОРЫНСЫЗДЫҒЫНА КЛИНИКАЛЫҚ-ДИАГНОСТИКАЛЫҚ
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Аңдатпа. Балалардағы пневмония қазіргі педиатрияның өзекті мәселелерінің бірі болып қала береді, бұл аурудың жоғары таралуымен және уақтылы диагностикаланбаған жағдайда асқынулардың даму қаупімен байланысты. Кеуде қуысы ағзаларының рентгенографиясы диагнозды растаудың кеңінен қолданылатын әдісі болып табылады, алайда аурудың ерте кезеңдерінде оны қолдану төмен диагностикалық ақпараттылықпен сипатталып, негізсіз жоғары сәулелік жүктемеге әкелуі мүмкін.

Классикалық түсінік бойынша үлестік пневмония дамуының төрт сатысы ажыратылады: қан толу (прилив), қызыл және сұр бауырлану (опеченение) және жазылу сатысы. Ерте кезеңдерде (қан толу сатысы) өкпе тініндегі морфологиялық өзгерістер минималды болады, бұл рентгенологиялық бейнелеу мүмкіндігін шектейді.

Зерттеудің мақсаты балаларда пневмонияға күдік кезінде кеуде қуысы ағзаларының рентгенографиясын алғашқы тәулікте жүргізудің диагностикалық мақсаттылығын бағалау және зерттеуді кешіктіріп орындаудың сәулелік жүктемені азайту тұрғысынан артықшылықтарын негіздеу болды.

Зерттеу Шымкент қалалық №3 емханасында жүргізілді. Клиникалық түрде расталған пневмониясы бар 1–3 жас аралығындағы 5 баланың рентгенологиялық деректері талданды. Рентгенография аурудың бірінші тәулігінде және үшінші тәулігінде қайталап орындалды. Сонымен қатар 10 жалпы практика дәрігеріне анкеталық сауалнама жүргізіліп, клиникалық тактикасы мен сәулелік жүктеме туралы хабардарлық деңгейі бағаланды.

Аурудың бірінші тәулігінде барлық пациенттерде рентгенологиялық өзгерістер анықталмады, клиникалық белгілер болғанына қарамастан. Үшінші тәулікте барлық балаларда өкпе тініндегі қабыну үдерісіне тән рентгенологиялық өзгерістер анықталды. Қайталама зерттеу жалпы сәулелік жүктеменің екі есеге артуына әкелді. Сауалнама нәтижелері бойынша дәрігерлердің 70%-ы рентгенографияны аурудың алғашқы тәулігінде тағайындайды, ал тек 40%-ы ғана ерте кезеңдерде зерттеудің төмен ақпараттылығын біледі.

Осылайша, балаларда пневмонияға күдік кезінде кеуде қуысы ағзаларының рентгенографиясын алғашқы тәулікте жүргізу морфологиялық өзгерістердің жеткіліксіз айқын болуына байланысты төмен диагностикалық құндылыққа ие. Зерттеуді кешіктіріп орындау оның ақпараттылығын арттырып, сәулелік жүктемені диагностикалық сапаны төмендетпей азайтуға мүмкіндік береді.

Түйін сөздер: пневмония, пневмония сатылары, рентгенография, сәулелік жүктеме, кешіктірілген диагностика.

КЛИНИКО-ДИАГНОСТИЧЕСКОЕ ОБОСНОВАНИЕ НЕРАЦИОНАЛЬНОСТИ ВЫПОЛНЕНИЯ РЕНТГЕНОГРАФИИ ОРГАНОВ ГРУДНОЙ КЛЕТКИ В ПЕРВЫЕ СУТКИ ПРИ ПОДОЗРЕНИИ НА ПНЕВМОНИЮ У ДЕТЕЙ

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Аннотация. Пневмония у детей остаётся актуальной проблемой современной педиатрии в связи с высокой распространённостью заболевания и риском развития осложнений при несвоевременной диагностике. Рентгенография органов грудной клетки широко используется для подтверждения диагноза, однако её применение в ранние сроки заболевания может обладать низкой диагностической информативностью и сопровождаться неоправданным увеличением лучевой нагрузки.

Классически выделяют четыре стадии развития долевой пневмонии: стадия прилива, красного и серого опеченения, а также стадия разрешения. На ранних этапах (стадия прилива) морфологические изменения в лёгочной ткани выражены минимально, что ограничивает возможности рентгенологической визуализации.

Цель исследования: оценить диагностическую целесообразность выполнения рентгенографии органов грудной клетки в первые сутки при подозрении на пневмонию у детей и обосновать преимущества отсроченного проведения исследования с позиции снижения лучевой нагрузки.

Исследование проведено на базе городской поликлиники №3 г. Шымкента. Проанализированы рентгенологические данные 5 детей в возрасте от 1 до 3 лет с клинически подтверждённой пневмонией. Рентгенография выполнялась в первый день заболевания и повторно на третьи сутки. Дополнительно проведено анкетирование 10 врачей общей практики с целью оценки клинической тактики и уровня осведомлённости о лучевой нагрузке.

На первый день заболевания у всех пациентов рентгенологические изменения отсутствовали, несмотря на наличие клинических признаков пневмонии. На третьи сутки у всех детей выявлены характерные рентгенологические признаки воспалительного процесса в лёгких. Повторное исследование приводило к двукратному увеличению

суммарной лучевой нагрузки. По данным анкетирования, 70% врачей назначают рентгенографию в первые сутки заболевания, при этом лишь 40% осведомлены о низкой информативности исследования на ранних стадиях.

Выполнение рентгенографии органов грудной клетки в первые сутки при подозрении на пневмонию у детей обладает низкой диагностической ценностью в связи с ранней стадией морфологических изменений заболевания. Отсроченное проведение исследования повышает его информативность и позволяет снизить лучевую нагрузку без ухудшения качества диагностики.

Ключевые слова: пневмония, стадии пневмонии, рентгенография, лучевая нагрузка, отсроченная диагностика.

Introduction. Pneumonia in children remains one of the most significant problems in modern pediatrics due to its high prevalence and the risk of complications associated with delayed diagnosis. In clinical practice, chest radiography is traditionally used as the primary method for confirming the diagnosis; however, its use requires strict justification, particularly considering the increased sensitivity of the pediatric organism to ionizing radiation.[4]

According to classical concepts established more than a century ago, lobar pneumonia progresses through four consecutive stages: congestion, red hepatization, gray hepatization, and resolution. During the congestion stage (days 2–3 of illness), hyperemia and pulmonary tissue edema predominate, accompanied by increased capillary permeability and the onset of exudation. However, at this stage, structural changes in the alveoli are insufficiently pronounced, which limits their visualization on radiographic examination.

In the subsequent stages—red hepatization (days 4–6) and gray hepatization (days 7–9)—there is accumulation of exudate within the alveolar spaces, increased cellular infiltration, fibrin deposition, and consolidation of lung tissue. It is during these stages that morphological changes become detectable by radiographic imaging. During the resolution stage (days 9–11), gradual resorption of exudate and restoration of normal lung structure are observed.[5],[6]

Clinical presentation and physical examination findings, particularly auscultation, are closely related to the stage of the inflammatory process. In the early stages of the disease, findings such as diminished vesicular breath sounds, crepitation, harsh breathing with prolonged expiration, as well as localized moist and dry rales may be present. As the disease progresses, auscultatory findings become more pronounced, allowing suspicion of pneumonia even before clear radiographic changes appear.[7]

Thus, analysis of the medical history and auscultatory findings allows the clinician to roughly assess the stage of the disease and determine management strategy. However, performing chest radiography within the first 24 hours in the absence of established morphological changes may reduce the diagnostic value of the study. In some cases, a negative early radiographic result may mislead the clinician and potentially delay the initiation of therapy.

Despite this, in clinical practice, chest radiography is often performed within the first day of illness when its diagnostic value remains low. This leads to an unjustified increase in radiation exposure without providing significant diagnostic information. An additional factor is the

common practice of performing follow-up radiography after completion of treatment, even in cases of favorable clinical dynamics.[8]

Therefore, reconsideration of the timing and indications for radiological examination in children with suspected pneumonia is warranted. A rational approach based on initial clinical assessment with auscultatory findings, followed by radiography at later stages of the disease (e.g., on day 3), may help reduce unnecessary radiation exposure without compromising diagnostic accuracy.

The aim of this study is to provide a clinical and diagnostic justification for delayed chest radiography in children with suspected pneumonia from the perspective of minimizing radiation exposure.[9],[10]

Materials and Methods. The study was conducted at City Polyclinic No. 3 in Shymkent. Radiological data from five children aged 1–3 years with clinically confirmed pneumonia were analyzed. All examinations were performed with informed parental consent and in the presence of their parents.

All patients were monitored from the onset of the first clinical symptoms of the disease. At the initial stage, diagnosis was based on medical history taking, assessment of complaints, and findings of the physical examination, including mandatory chest auscultation. Particular attention was paid to characteristic auscultatory findings such as decreased breath sounds, crepitation, as well as moist and dry rales.

Chest radiography was performed over the course of the disease: on the first day after the onset of clinical manifestations and repeated on the third day. For each patient, a comparative analysis of radiological findings was carried out at both the early and delayed stages of the disease.

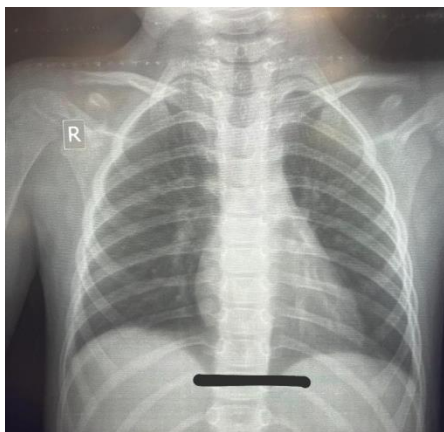


Figure1- In Patient No. 1, no radiographic evidence of pneumonia was observed on the chest radiograph on day 1 of illness.



Figure2- In Patient No. 1, chest radiography performed on day 3 of illness demonstrated marked radiographic findings consistent with left lower lobe pneumonia.

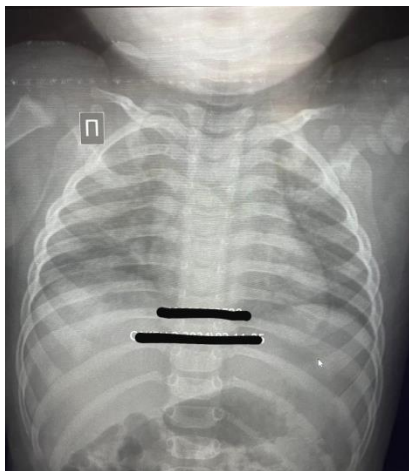


Figure3- In Patient No. 2, no radiographic evidence of pneumonia was observed on the chest radiograph on day 1 of illness.



Figure4- In Patient No. 2, chest radiography performed on days 3–4 of illness revealed radiological signs consistent with bilateral bronchopneumonia.

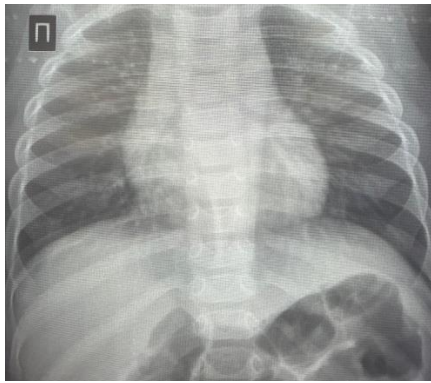


Figure5- In Patient No. 3, no radiographic evidence of pneumonia was observed on the chest radiograph on day 1 of illness.

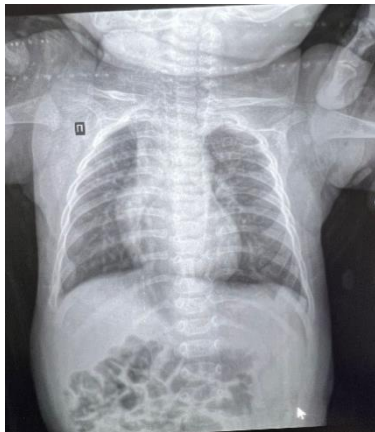


Figure6- In Patient No. 3, chest radiography performed on days 3–4 of illness demonstrated radiological findings consistent with bilateral bronchopneumonia.

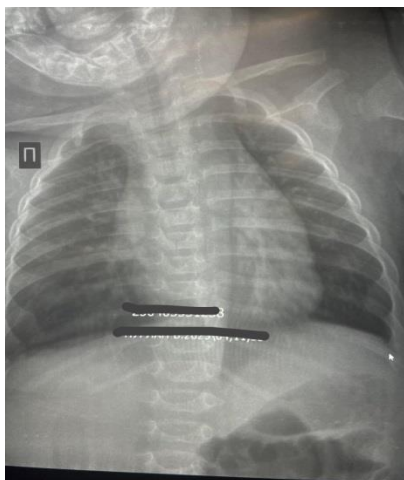


Figure7- In Patient No. 4, no radiographic evidence of pneumonia was observed on the chest radiograph on day 1 of illness.



Figure8- In Patient No. 4, chest radiography performed on day 4 of illness demonstrated radiological findings consistent with bilateral bronchopneumonia.

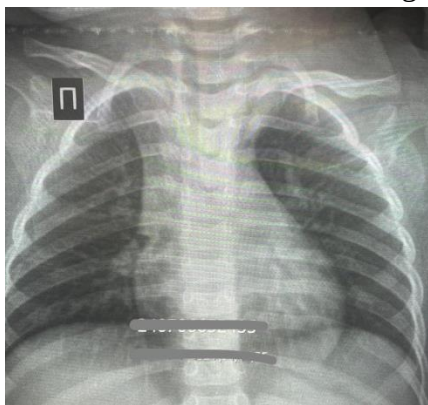


Figure9- In Patient No. 5, no radiographic evidence of pneumonia was observed on the chest radiograph on day 1 of illness.

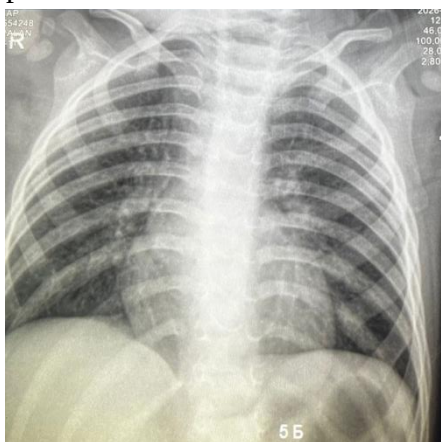


Figure10. In Patient No. 5, chest radiography performed on day 3 of illness demonstrated radiological findings consistent with bilateral bronchopneumonia.

In addition, the dosimetric exposure received by patients during radiological examinations was evaluated. The mean effective dose of a single chest radiograph in children was estimated at approximately 0.02–0.05 mSv. Thus, when the examination was performed on the first day and repeated on the third day, the cumulative radiation exposure was approximately doubled, which is of clinical relevance in pediatric practice given the increased radiosensitivity of the child's organism.

In addition, a paper-based questionnaire survey was conducted among general practitioners (GPs) to assess their clinical approach in cases of suspected pneumonia in children, including the timing of chest radiography and attitudes toward radiation exposure. The

questionnaire included items regarding the preferred timing of radiological examination, reliance on clinical findings in establishing the diagnosis, and the frequency of follow-up chest radiography after treatment.

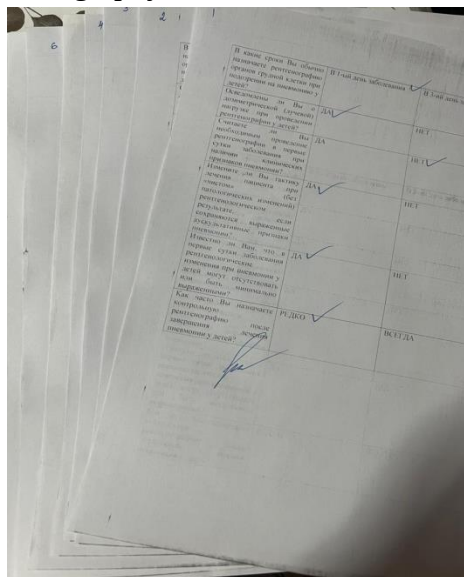


Figure11- Paper-based questionnaire survey

The questionnaire included the following items:

- At what time points do you usually prescribe chest radiography in children with suspected pneumonia?
- Are you aware of the radiation (dosimetric) exposure associated with chest radiography in children?
- Do you consider chest radiography necessary on the first day of illness in the presence of clinical signs of pneumonia?
- Would you modify your treatment approach if a chest radiograph shows no pathological changes, while pronounced auscultatory signs of pneumonia persist?
- Are you aware that radiographic changes in pediatric pneumonia may be absent or minimally expressed during the first day of illness?
- How often do you prescribe follow-up chest radiography after completion of pneumonia treatment in children?

Ethical Considerations. The study was conducted in accordance with the fundamental principles of medical ethics and confidentiality. Personal data of the pediatric patients included in the study were not used and are not subject to disclosure. All results are presented in an aggregated form without any identifying information.

Similarly, data obtained from the questionnaire survey of general practitioners were analyzed anonymously. Personal data of respondents, as well as the specific name of the healthcare institution where the survey was conducted, are not disclosed. Participation of physicians in the study was voluntary, and data processing was performed in a de-identified form.

The study was observational in nature and did not infringe upon the rights of patients or medical personnel.

Results. Analysis of radiological data from five pediatric patients aged 1–3 years with clinically confirmed pneumonia demonstrated that on the first day of illness, no radiographic

abnormalities of the chest were detected in all patients (100%). However, the clinical presentation in all examined cases corresponded to the initial manifestations of pneumonia, including characteristic auscultatory findings.

On repeat chest radiography performed on day 3 of illness, all five children (100%) showed radiographic signs of inflammatory changes in the lung parenchyma consistent with pneumonia of varying severity. Thus, the diagnostic yield of chest radiography significantly increased when the examination was performed at a delayed time point.

Analysis of radiation exposure demonstrated that when chest radiography was performed twice (on days 1 and 3), the cumulative radiation dose was doubled compared to a single examination, which is of clinical importance in pediatric practice.

According to the results of the questionnaire survey of general practitioners (GPs), in which 10 specialists participated, the following was established:

- 70% of physicians (7 out of 10) prescribe chest radiography within the first day of suspected pneumonia in children;
- 60% (6 out of 10) of respondents are aware of the radiation (dosimetric) exposure associated with radiological examinations in children;
- 65% (6–7 out of 10) of physicians reported that they may modify treatment tactics in cases of a “normal” chest radiograph on the first day of illness, even in the presence of pronounced auscultatory signs;
- 40% (4 out of 10) of respondents are aware that radiographic changes in pediatric pneumonia are often absent or minimally expressed during the first day of illness;
- 70% (7 out of 10) of physicians regularly prescribe follow-up chest radiography after completion of treatment.

Thus, the obtained data indicate a high frequency of early chest radiography prescription and insufficient awareness among a proportion of physicians regarding the temporal evolution of radiographic changes in pediatric pneumonia, which may contribute to unnecessary radiation exposure.

Proposed solution to the problem

To reduce excessive radiation exposure in children with suspected pneumonia, the implementation of a stepwise clinical and diagnostic algorithm is proposed. It is based on the initial assessment of the patient's condition using medical history and physical examination, including mandatory chest auscultation, without obligatory chest radiography within the first day of illness in the absence of severe or life-threatening symptoms.[11],[12]

Chest radiography is recommended to be performed in a delayed manner, approximately on day 3 of illness, when the likelihood of detecting inflammatory changes is significantly higher. This approach allows for increased diagnostic yield while simultaneously reducing the number of low-informative examinations.

In addition, it is recommended to limit routine follow-up chest radiography after treatment in cases with clear positive clinical dynamics, reserving it only for strict clinical indications (prolonged course, complications, or lack of improvement). An important component of this approach is improving the awareness of general practitioners regarding the temporal evolution of radiographic changes in pediatric pneumonia, as well as the fact that radiographic

findings may be normal during the first day of illness. This can be achieved through regular training seminars, clinical guidelines, and standardized patient management algorithms.[13]

Regular seminars, lectures, and workshops for primary care physicians are recommended, focusing on the stages of pneumonia and the characteristics of early radiographic manifestations.

Radiation exposure awareness

Systematic improvement of healthcare professionals' awareness regarding radiation doses associated with pediatric radiological examinations and principles of radiation safety is essential.

Thus, the implementation of a clinically oriented approach with delayed chest radiography allows for optimization of pneumonia diagnosis in children, reduction of radiation exposure, and improvement in the rational use of diagnostic resources.

Conclusion. The conducted study demonstrated that in children with clinically confirmed pneumonia, no radiographic abnormalities were detected on the first day of illness in all observed patients (100%), whereas on day 3, all children (100%) showed characteristic signs of inflammatory changes in the lung parenchyma. This indicates a higher diagnostic yield of chest radiography when performed in a delayed manner.

It was additionally established that performing chest radiography on the first day of illness and repeating it on day 3 results in a twofold increase in cumulative radiation exposure, which is a significant factor in pediatric practice given the high radiosensitivity of the child's organism.

The results of the questionnaire survey of general practitioners (n = 10) revealed that a considerable proportion of specialists prescribe chest radiography at early stages of the disease; however, insufficient awareness was noted regarding the temporal progression of radiographic changes in pediatric pneumonia and the risks of excessive radiation exposure.

Thus, the proposed clinical and diagnostic approach, based on the initial assessment of the patient's condition using medical history and auscultatory findings with delayed chest radiography (approximately on day 3 of illness), allows for improved diagnostic efficiency and reduced radiation exposure without compromising diagnostic quality.

It is recommended that this approach be implemented in clinical practice and that awareness among primary care physicians regarding the rational use of radiological methods in suspected pediatric pneumonia be enhanced.

Implementation of clinical guidelines and management algorithms

Development and wide dissemination of standardized protocols regulating indications and optimal timing for chest radiography in pediatric pneumonia, with emphasis on delayed imaging in clinically stable patients.

Emphasis on primary diagnosis based on medical history and auscultatory findings, with chest radiography performed only when clinically indicated or in a delayed manner.

Quality control of medical care

Monitoring the frequency of chest radiography in children with pneumonia at the primary care level and analysis of the appropriateness of imaging studies, followed by feedback to physicians.

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CIRCULAR RESECTION OF THE CENTRAL PART OF THE LARGE DIAGNOSE WITH ONCOLOGICAL STENOSIS (clinical case)

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Abstract. Because laryngeal stenosis leads to progressive respiratory failure, most patients with this condition require surgical treatment. Tracheal stenosis can be caused by injuries, infectious diseases, cicatricial strictures developing after tracheostomy or intubation, as well as tracheal tumors. The issue calls for improving surgical treatment methods for tracheal stenosis and refining anesthesiological intervention techniques.

To improve the level of surgical treatment for tracheal stenosis by taking into account the tumor's location, growth direction, length of the narrowing, the risks and benefits of surgical therapy, and the specifics of anesthesiological interventions.

A patient with subglottic carcinoma developed a tracheal stenosis. Airflow through the trachea became severely obstructed, forcing them to breathe on humidified oxygen for several weeks. Due to respiratory failure, he was referred to an oncology clinic and underwent surgical treatment. Tracheoscopy revealed an exophytic tumor measuring 2x3 cm, extending from the mucosa of the lower larynx to the level of the second tracheal ring and occupying more than 80% of the tracheal lumen.

The operation began with intubation under general anesthesia through a tracheostomy tube. After the skin was prepared and the tumor area was completely excised, hemostasis was achieved, and then a circular incision was made below the tumor, including two tracheal rings. Hyperoxemia was achieved before the tracheal incision, and temporary artificial apnea was established during the cut. After the tracheal incision, the endotracheal tube was repositioned below the incision site, and anesthesia was continued. After the tumorous portion of the trachea was completely excised, the endotracheal tube was repositioned. Running sutures were placed between the tracheal rings along the tube, tightened, and secured to create a watertight seal. After an aseptic dressing was applied to the wound, the thyroid cartilage was sutured to the chest skin to prevent tracheal elongation. There are no signs of respiratory insufficiency

The course and outcomes of tracheal circular resection surgery were discussed at the Oncology Center Clinical Conference, highlighting its challenges and successes, as well as the specifics of anesthesia.

Improving the surgical treatment options and anesthesia management for tracheal stenosis caused by cancer or other factors.

Keywords: oncology, tracheal stenosis, surgical treatment, respiratory failure, circular resection.

ОНКОЛОГИЯЛЫҚ НЕГІЗДЕ СТЕНОЗҒА ҰШЫРАҒАН КЕҢІРДЕКТІ ЦИРКУЛЯРЛЫ РЕЗЕКЦИЯЛАУ (клиникалық жағдай)

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Аңдатпа. Үдемелі тыныс жетімсіздігіне алып келетіндігіне байланысты кеңірдек стенозымен зардап шегетін науқастардың көбі хирургиялық емге мұқтаж. Кеңірдек стенозына жарақаттар, инфекциялық аурулар, трахеостомиядан, интубациядан кейін дамитын тыртықтық тарылулар сонымен қатар кеңірдек ісіктері де алып келуі мүмкін. Мәселе, кеңірдек стенозын хирургиялық жолмен емдеу тәсілін, анестезиологиялық араласу жолдарын жетілдіруді қажет етеді.

Кеңірдек стенозында ісіктің орналасуын, өсу бағытын, тарылу ұзындығын, оталық емнің тәуекелдері мен артықшылықтарын, анестезиологиялық араласулар ерекшеліктерін ескере отырып, хирургиялық ем деңгейін жетілдіру.

Көмей асты обырымен ауыратын науқаста кеңірдек тарылуы (стриктурасы) дамыған. Кеңірдектен ауа өтуі мүлдем қиындап бірнеше апта ылғалданған оттегімен демалуға мәжбүр болған. Тыныс жетімсіздігіне байланысты онкологиялық диспансерге жолданып, хирургиялық ем қабылдаған. Трахеоскопия арқылы экзофитті өскен ісік көлемі 2х3 см, көмей төменгі бөлігі шырышты қабаты мен 2 кеңірдек сақинасы деңгейінде өскендігін, кеңірдек кеңістігінің 80% астам бөлігін қамтып жатқандығы анықталды.

Ота трахеостомиялық түтік арқылы интубациялық жансыздандыру аясында басталды. Терісі өңделіп, кесу арқылы ісік аумағы толық аршылып, гемостаз жасалған соң, ісіктің төменгі тұсынан екі кеңірдек сақинасын қоса циркулярлы кесу жасалды. Кеңірдек кесілу алдында гипероксигенация жасалып, кесілу кезінде уақытша жасанды апное жағдайы қалыптастырылды. Кеңірдек кесілген соң интубациялық түтік кеңірдектің кесілген тұсынан төменгі бөлігіне ауыстырылып, наркоз жалғастырылды. Кеңірдектің ісікке ұшыраған тұсы толық сылынып алынған соң, интубациялық түтік бұрынғы орынына қойылды. Түтік бойымен кеңірдек сақиналары арасына түйінді тігіс салынып, тартылып, герметикалық бекітілді. Жараға асептикалық таңғыш қойылғаннан соң кеңірдек созылмас үшін оның йегі төс терісіне тігіліп, бекітілді. Ота нәтижесінде кеңірдектің ауа өткізу қабілеті толық қалыпқа келтірілді. Тыныс жетімсіздігі белгісі жоқ.

Кеңірдектің циркулярлы резекциясы отасының барысы мен нәтижесі онкологиялық орталық клиникалық конференциясында талқыланып, қиындықтары мен жетістіктері, наркоз ерекшеліктері аталып өтті.

Обыр негізінде немесе басқа да себептермен туындаған кеңірдек стенозын оталық емдеу мүмкіншіліктерін, анестезия ерекшеліктерін жетілдіру.

Түйін сөздер: онкология, кеңірдек стенозы, хирургиялық ем, тыныс жетімсіздігі, циркулярлы резекция.

ЦИРКУЛЯРНАЯ РЕЗЕКЦИЯ ТРАХЕИ ПРИ ОПУХОЛЕВОМ СТЕНОЗЕ (клинический случай)

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Аннотация.. Стеноз трахеи, особенно онкологического генеза часто сопровождается с прогрессирующей дыхательной недостаточностью которая требует немедленного хирургическому вмешательству. Причинами стеноза трахеи могут быть травматические, инфекционные, постинтубационные, посттрахеостомические, онкологические и другие факторы. По этому возникает необходимость совершенствовать хирургических методов лечения и анестезиологических подходов. Проанализировать риски и преимущества оперативного вмешательства при циркулярной резекции трахеи, учитывая расположения, характера роста опухоли, степени стеноза и протяженности а так же методов анестезии и интубации трахей.

У больного страдающего раком трахеи, подгортанной области, развивалась стриктура трахеи с дыхательной недостаточностью. Из за чего больной был вынужден принимать дополнительно оксигенацию. При трахеоскопии выявлена экзофитная опухоль размером 2×3 см, распространяющаяся от слизистой оболочки нижнего отдела гортани до уровня второго кольца трахеи и занимающая более 80% просвета трахеи. Больной направлен на хирургическое лечение в онкологический диспансер, где и был оперирован. Операция началась на фоне интубационного обезболивания через трахеостомическую трубку. После обработки кожи, полной мобилизации опухоли и гемостаза, проведена циркулярная резекция, трахеи с удалением два колцеобразных хряща в нижней части опухоли. Учитывая неизбежность временного апноэ во время операции, перед вскрытием трахеи была проведена гипероксигенация. После разреза дистальных колец трахеи, интубационная трубка была заменена на нижнюю часть. Интубационную трубку поставили на прежнее место после того, как опухолевая часть гортани была полностью отсепарирована. Проксимальная и дистальная часть трахеи зашиты узловыми швами, натянута и герметично закреплена. После наложения асептической повязки на рану, во избежание растяжения трахеи, подбородок больного пришит

и закреплён к груди. В послеоперационном периоде клинических проявлений дыхательной недостаточности нет.

Ход и результаты операции по циркулярной резекции гортани были обсуждены на клинической конференции онкологического центра, где были отмечены трудности и достижения, особенности наркоза. Основной целью работы является совершенствование возможности оперативного лечения стеноза трахеи, вызванных раком или другими причинами и особенностей анестезии.

Ключевые слова: онкология, стеноз трахеи, хирургическое лечение, дыхательная недостаточность, циркулярная резекция.

Introduction

1 Purpose of the study. Tracheal stenosis, particularly when caused by cancer, is often accompanied by progressive respiratory failure, which requires immediate surgical intervention.

To improve the level of surgical treatment for tracheal stenosis by taking into account the tumor's location, growth direction, length of the narrowing, the risks and benefits of operative therapy, and the specifics of anesthesiological interventions.

A patient who had undergone tracheal reconstruction 30 years earlier using a neck skin flap presented with clinical signs of tracheal stenosis and underwent surgical treatment. A successful circular tracheal resection was performed; histological analysis of the specimen revealed a keratinizing squamous cell carcinoma that had developed from the mucosal lining of the skin flap used during the initial surgery. The postoperative period was uneventful. The authors note that detecting a tumor arising from the skin flap during the postoperative period is particularly challenging [1]. Kokshetau's surgical oncologists report that during the surgical treatment of a locally advanced thyroid gland tumor, four rings of the trachea were successfully resected. The doctors recommend closely monitoring the anastomosis site after surgery, keeping it clean, and performing regular decontamination to prevent infectious complications [2]. The following authors, through a retrospective review of the records of 84 patients who underwent surgical treatment for cicatricial tracheal stenosis between 2018 and 2023, examined the preoperative stenosis level, patients' age, sex, comorbidities, and recommend preventing potential subsequent complications [3].

The following authors, who performed surgery on six patients with tracheal stenosis by means of a circular resection, recommended wearing a special neck orthosis for 7–13 days postoperatively. It immobilizes the neck, helping to prevent the tracheal sutures from tearing apart due to neck movement. None of the six patients developed suture insufficiency [4]. The surgeons of the Russian Scientific Center for Child Health report that, after surgically treating 26 children with tracheal stenosis for various reasons, they achieved the following results. Of the 26 children who underwent surgery for tracheal stenosis for various reasons, 24 (92.3%) had good outcomes, while 2 patients (7.69%) died from postoperative complications. The authors noted that the effectiveness of tracheal resection largely depends on the length of the stricture [5].

A 75-year-old patient presented with complaints of respiratory insufficiency. Examination (CT) revealed a tumor located 8 cm above the tracheal bifurcation, occupying approximately 90% of the tracheal lumen. The patient successfully underwent an endoscopic procedure - specifically, recanalization using a neodymium-YAG laser. The authors advocate for the effectiveness of this approach in cases where open surgery is contraindicated [6].



In analyzing the causes of 98 patients with tracheal stenosis, Yu.S. Yesakov and colleagues found that 58 of them developed after tracheostomy, 31 after intubation, 6 patients due to trauma, 2 patients due to tumoral stenosis, and 1 patient developed a postoperative stricture [7]. It is clear that neoplastic stenosis of the trachea is a relatively rare condition (2%). This is because various congenital stenoses develop mainly on the basis of fetal malformations, while acquired ones develop as a result of various injuries of the trachea (most often iatrogenic; through intubation, tracheostomy tubes), chronic inflammation, and infectious processes [5,8]. Considering the level (location) of the tracheal stenosis, in 61 patients the stenosis was located in the Figure

1: Tumor appearance on computed tomography

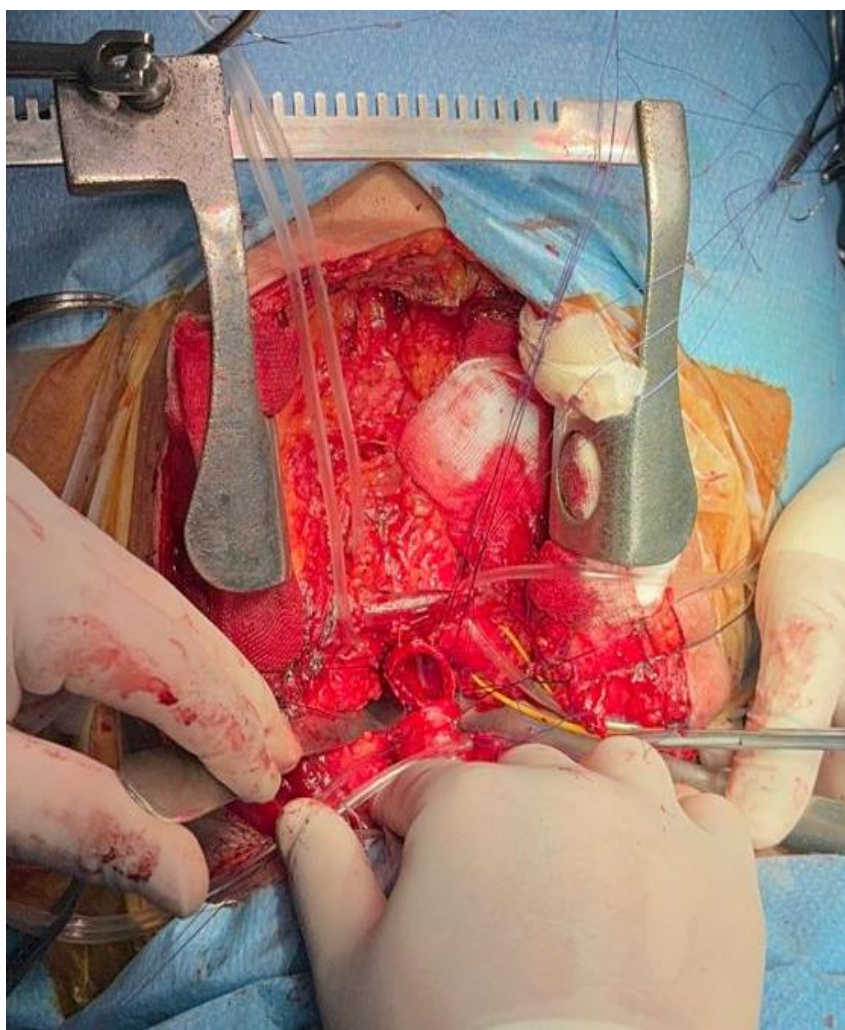
cervical part, in 29 patients in the thoracic part, of which the stenosis was located above the tracheal bifurcation in 4 patients. Long (2-8 cm) stenoses affecting both the cervical and thoracic parts of the trachea were found in 5 patients [6,10]. The Tashkent Medical Academy also studied the subsequent fate of 186 patients who underwent surgical treatment for laryngeal stenosis, and found that 165 (88.5%) of them had an iatrogenic cause, developing after resuscitation measures. They noted that 180 patients had a good and satisfactory outcome after the surgical treatment, and 6 patients died as a result of various complications [9]. The problem of preventing anastomosis separation after circular resection due to tracheal stenosis is also a matter of much debate among scientists, and various suggestions have been made. One of them is to fix the distal end of the trachea to the inner surface of

the sternum after the anastomosis is performed to prevent (reduce) tension in the suture area, or to lung tumor reinforce the main suture by placing an additional suture

between the tracheal rings using Vicryl or Polysorb threads, one end of which is fixed to the lower horn of the thyroid cartilage or the hyoid bone [11]. Kovalev M.G. and colleagues wrote that in the surgical treatment of bronchial stenosis, it is necessary not only to improve surgical techniques, but also to improve anesthetic measures, and to introduce new technologies. They considered alternative methods due to the difficulty of intubation in the cervical part of the trachea. Depending on the severity of the stenosis, it is recommended to image of a introduce a special I-Gel tube through the supraglottic airway and perform high-frequency ventilation of the lungs, or stenting the narrowed area under sedation [11].

Figure 2. View from the stage of tracheal resection

2 Clinical case report. I would like to present to your attention information about the circular resection of the larynx, which was successfully performed in the "City Multidisciplinary Hospital with an Oncology Center" in Shymkent. Patient T., 42 years old, has been undergoing treatment for cervical and subglottic cancer for several months. During chemotherapy and radiation therapy, the patient gradually developed a narrowing of the larynx (stricture). He was forced to breathe with humidified oxygen for several weeks. Due to the growth of the tumor, it became completely difficult for air to pass through the larynx, and shortness of breath began to develop.



Tracheoscopy revealed an exophytic tumor measuring 2x3 cm, extending from the mucosa of the lower larynx to the level of the second tracheal ring and occupying more than 80% of the tracheal lumen.

As a result, he was examined by a doctor and sent to an oncology clinic. The operation was performed through the neck. Under intubation anesthesia, after the surgical site was cleaned and sterilized, an incision was made in the skin.

Hemostasis was achieved with an electrocoagulator, depending on the stage of the operation. The stenosed segment of the trachea was carefully isolated, and after the distal trachea was transected, the breathing tube was temporarily repositioned there. The portion of the trachea containing the tumor was gradually isolated by cutting, then circularly excised and removed. Using the ligature as a guide,



the tracheal rings in its distal segment and proximal margin were tied together. At this stage, the intubation tube was returned to its original position. The staged, interrupted sutures were placed around the tracheal tube using it as a guide. The tracheal edges were brought into full, airtight contact. Hemostasis was meticulously maintained during the procedure. Layered sutures were placed sequentially, the skin was closed, and hemostasis was achieved with a dry field. After applying aseptic dressings, to prevent tracheal elongation, the patient's chin was pulled down toward the chest and secured with sutures.

The direct surgical procedure began under intravenous anesthesia, after the trachea was cut below the

Figure 3 shows a macroscopic specimen of a tumor

level of the tumor, a No. 6.0 intubation tube (taking into account the endophytic growth of the tumor) was inserted into the space of its distal part, and inhalation anesthesia was continued.

Artificial respiration was performed in VCV mode. During tracheal reconstruction, 3 2-minute artificial apneas were performed as needed during the surgical phase (manipulations, suturing, cutting,

etc.). Before temporary respiratory arrest, 100% hyperoxygenation with O₂ was performed, and the blood was pre-saturated with oxygen.

Towards the end of the operation, a bronchoscope was inserted through the tube, endotracheal intubation was performed, and endoscopic monitoring of the anastomosis was performed. In the postoperative period, after the patient was fully awake, extubation was performed in the usual manner. The postoperative period was uneventful and without complications. The patient was discharged home on the 8th day with recommendations.

Discussion. Given the importance of the surgical field and the complexity of its location, the operation must be performed very carefully and quickly. Even small bleeds are dangerous due to aspiration.

Since the tracheal incision and tumor excision phase requires temporary apnea, preoperative hyperoxygenation is necessary, which demands a high level of anesthesiological support. After the trachea was incised, the endotracheal tube was repositioned distally from the incision site, and anesthesia was continued. After the tumorous portion of the trachea was completely excised, the endotracheal tube was repositioned, and anesthesia and surgery were continued. Upon completion of the surgery, the patient showed no signs of hypoxia or other complications.

Conclusion. At the Shymkent City Oncology Center, the surgical treatment of tracheal stenosis caused by cancer was successfully completed. In the next phase, it is necessary to further refine the stages of surgical intervention and the level of anesthesiological support.

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CIRCULAR RESECTION OF THE CENTRAL PART OF THE LARGE
DIAGNOSE WITH ONCOLOGICAL STENOSIS (clinical case)

YASSAWI JOURNAL OF HEALTH SCIENCES

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