



## ARTIFICIAL INTELLIGENCE-AUGMENTED CERVICAL CANCER PREVENTION IN THE HPV-PRIMARY SCREENING ERA: DIGITAL CYTOLOGY, AUTOMATED COLPOSCOPY, AND RISK-BASED TRIAGE

**Mamadaliyeva Bakhora**

Samarkand State Medical University, Samarkand, Uzbekistan

### Abstract

**Background.** Cervical cancer remains a major but largely preventable gynecological malignancy. Primary human papillomavirus testing improves screening sensitivity, although its limited specificity creates a need for effective triage of HPV-positive women. Artificial intelligence may increase the accuracy, reproducibility, and scalability of cytology and colposcopy interpretation.

**Materials and methods.** A structured narrative review was conducted using current World Health Organization recommendations and recent multicenter studies of deep-learning-assisted liquid-based cytology, compact digital microscopy, automated visual evaluation, and artificial-intelligence-supported colposcopy. Evidence was assessed according to diagnostic performance, external validation, workflow efficiency, interpretability, equity, and clinical implementation.

**Results.** Recent multicenter systems have demonstrated that deep-learning-assisted cytology can improve sensitivity compared with conventional interpretation and substantially reduce slide-reading time. Low-cost compact microscopy combined with transformer-based analysis has shown clinically relevant performance in resource-limited settings. Artificial-intelligence-supported colposcopy can identify the transformation zone, localize suspicious epithelium, estimate the probability of cervical intraepithelial neoplasia grade 2 or worse, and support biopsy selection. The most promising clinical architecture is not autonomous diagnosis but a multimodal pathway combining HPV genotype, cytological morphology, colposcopic appearance, age, immune status, and previous screening history. Principal limitations include dataset shift, staining variability, inadequate representation of rare lesions, imperfect calibration, reduced performance in inflammatory or technically poor images, and insufficient prospective evidence that algorithm use reduces invasive cancer incidence.

**Conclusion.** Artificial intelligence may strengthen HPV-based cervical cancer prevention by improving triage, reducing specialist workload, and expanding access to screening. Routine implementation requires prospective multicenter validation, transparent uncertainty reporting, human oversight, quality assurance, and integration with reliable follow-up and treatment services.

**Keywords:** cervical cancer, human papillomavirus, artificial intelligence, cervical cytology, colposcopy, cervical intraepithelial neoplasia, screening, digital pathology.

---

## ПРОФИЛАКТИКА РАКА ШЕЙКИ МАТКИ С ПРИМЕНЕНИЕМ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА В ЭПОХУ ПЕРВИЧНОГО ВПЧ-СКРИНИНГА: ЦИФРОВАЯ ЦИТОЛОГИЯ, АВТОМАТИЗИРОВАННАЯ КОЛЬПОСКОПИЯ И РИСК-ОРИЕНТИРОВАННАЯ СОРТИРОВКА

**Мамадалиева Бахора**

Самаркандский государственный медицинский университет, Самарканд, Узбекистан

**Аннотация**

**Актуальность.** Рак шейки матки остается значимой, но в значительной степени предотвратимой злокачественной опухолью женской репродуктивной системы. Первичное тестирование на вирус папилломы человека повышает чувствительность скрининга, однако его ограниченная специфичность требует эффективной сортировки ВПЧ-положительных пациенток. Искусственный интеллект способен повысить точность, воспроизводимость и доступность цитологического и кольпоскопического исследования.

**Материалы и методы.** Выполнен структурированный нарративный обзор актуальных рекомендаций Всемирной организации здравоохранения и современных многоцентровых исследований глубинного обучения в жидкостной цитологии, цифровой микроскопии и автоматизированной кольпоскопии. Доказательства оценивались по диагностической эффективности, внешней валидности, влиянию на рабочий процесс, интерпретируемости, равноправию и возможности внедрения.

**Результаты.** Современные алгоритмы способны повышать чувствительность цитологического исследования и значительно сокращать продолжительность просмотра препаратов. Компактные недорогие микроскопы с алгоритмическим анализом создают возможности для скрининга в регионах с ограниченными ресурсами. Искусственный интеллект в кольпоскопии может определять зону трансформации, локализовать подозрительные участки, прогнозировать CIN2+ и помогать выбирать место биопсии. Наиболее перспективна мультимодальная модель, объединяющая генотип ВПЧ, цитологическую морфологию, кольпоскопическую картину, возраст, иммунный статус и анамнез скрининга.

**Закключение.** Искусственный интеллект может усилить эффективность ВПЧ-ориентированной профилактики рака шейки матки, однако его внедрение требует проспективной многоцентровой валидации, контроля качества, человеческого надзора и доступной системы последующего наблюдения и лечения.

**Ключевые слова:** рак шейки матки, вирус папилломы человека, искусственный интеллект, цитология шейки матки, кольпоскопия, цервикальная интраэпителиальная неоплазия, скрининг, цифровая патология.

---

**BIRLAMCHI HPV-SKRINING DAVRIDA SUN'IY INTELLEKT YORDAMIDA  
BACHADON BO'YNI SARATONINING OLDINI OLISH: RAQAMLI SITOLOGIYA,  
AVTOMATLASHTIRILGAN KOLPOSKOPIYA VA XAVFGA ASOSLANGAN TRIAJ**

**Mamadaliyeva Bahora**

Samarqand davlat tibbiyot universiteti, Samarqand, O'zbekiston

**Annotatsiya**

**Dolzarblik.** Bachadon bo'yni saratoni ayollar reproduktiv tizimining muhim, biroq ko'p hollarda oldini olish mumkin bo'lgan xavfli o'smasi bo'lib qolmoqda. Birlamchi odam papilloma virusi testi skrining sezgirligini oshiradi, ammo uning spetsifikligi cheklanganligi HPV-musbat ayollarni samarali triaj qilishni talab etadi. Sun'iy intellekt sitologiya va kolposkopiya natijalarining aniqligi, takrorlanuvchanligi hamda ommaviy qo'llanish imkoniyatini yaxshilashi mumkin.

**Material va usullar.** Jahon sog'liqni saqlash tashkilotining amaldagi tavsiyalari, suyuqlik asosidagi sitologiya, raqamli mikroskopiya va avtomatlashtirilgan kolposkopiyaga oid zamonaviy ko'p markazli tadqiqotlar asosida strukturaviy narrativ sharh bajarildi. Dalillar diagnostik samaradorlik, tashqi validatsiya, ish jarayoniga ta'sir, izohlanuvchanlik, tenglik va klinik joriy etish bo'yicha baholandi.

**Natijalar.** Chuqur o'rganishga asoslangan tizimlar sitologik tekshiruv sezgirligini oshirishi va preparatlarni ko'rish vaqtini qisqartirishi mumkin. Arzon ixcham mikroskoplar va transformer

algoritmlarining birlashtirilishi resurslari cheklangan hududlar uchun yangi imkoniyat yaratmoqda. Sun'iy intellekt kolposkopiya transformatsiya zonasini aniqlash, shubhali epitelial sohalarini belgilash, CIN2+ xavfini hisoblash va biopsiya joyini tanlashga yordam beradi.

**Xulosa.** Sun'iy intellekt HPV asosidagi bachadon bo'yni saratoni profilaktikasini kuchaytirishi mumkin. Biroq keng joriy etishdan oldin ko'p markazli validatsiya, sifat nazorati, inson nazorati va ishonchli kuzatuv hamda davolash tizimi zarur.

**Kalit so'zlar:** bachadon bo'yni saratoni, odam papilloma virusi, sun'iy intellekt, bachadon bo'yni sitologiyasi, kolposkopiya, servikal intraepitelial neoplaziya, skrining, raqamli patologiya.

**Introduction.** Cervical cancer is a biologically preventable malignancy because its principal causal pathway—persistent infection with oncogenic human papillomavirus—can be interrupted through vaccination, screening, treatment of precancerous lesions, and timely management of invasive disease. Nevertheless, current global estimates indicate that approximately 604,000 new cases and 280,000 deaths occurred in 2024, with the greatest burden concentrated in low- and middle-income countries. The World Health Organization continues to promote the 90–70–90 elimination strategy: vaccination of 90% of girls by 15 years of age, high-performance screening of 70% of women by ages 35 and 45, and appropriate treatment of 90% of women with precancer or invasive cancer [1, 2, 3]. Primary HPV testing is more sensitive for clinically significant cervical precancer than cytology alone and has become the preferred foundation of many screening programs. The central limitation is that most HPV infections are transient and do not progress to high-grade cervical intraepithelial neoplasia. Consequently, HPV-positive women require additional risk stratification to avoid unnecessary colposcopy, biopsy, anxiety, cost, and overtreatment. In May 2026, the World Health Organization issued updated guidance on HPV DNA genotyping in cervical screening. The recommendations emphasize the use of limited or extended genotyping to improve risk stratification and adapt triage strategies to the resources and follow-up capacity of each health system [3, 6, 10]. Artificial intelligence is increasingly being evaluated as a complementary layer within this HPV-primary framework. Its most clinically relevant tasks include automated quality control, detection of abnormal cells, whole-slide cytology classification, identification of the cervical transformation zone, lesion segmentation, prediction of CIN2+, biopsy guidance, and integration of multimodal risk factors.

**Materials and Methods.** A structured narrative review was performed using official World Health Organization recommendations and recent primary investigations published through July 2026. Priority was given to multicenter or externally validated studies involving whole-slide cervical cytology, compact digital microscopy, automated visual evaluation, colposcopy-image analysis, and multimodal risk prediction. The evidence was organized into five clinical domains: HPV-primary screening, artificial-intelligence-assisted cytology, automated colposcopy, multimodal risk stratification, and implementation in resource-limited settings. Diagnostic systems were assessed according to sensitivity, specificity, area under the receiver-operating-characteristic curve, calibration, external validation, reading time, model interpretability, subgroup performance, and influence on clinical decision-making. The proposed reference standard for future studies is histologically verified CIN2+ or CIN3+, adjudicated independently of the artificial-intelligence output. Studies using only expert image labels as the ground truth are useful for technical development but provide weaker evidence of clinical effectiveness.

**Results.** HPV testing identifies women at increased biological risk before morphological abnormalities become apparent. However, an HPV-positive result alone cannot determine whether a woman has transient infection, persistent infection, low-grade disease, or transforming precancer. Genotyping partially addresses this limitation. HPV16 and HPV18 carry high oncogenic risk, while additional genotypes may provide intermediate or lower risk. Yet genotype must be interpreted together with age, immune status, cytology, previous test results, pregnancy status, smoking, HIV

infection, and adherence to follow-up. Artificial intelligence can combine these variables into an individualized probability of CIN2+ or CIN3+. The output can then support one of several actions: immediate colposcopy, repeat HPV testing, cytological triage, biomarker testing, treatment, or routine recall. A risk-based model is clinically preferable to a rigid binary classifier. A woman with persistent HPV16, high-grade cytology, and a suspicious transformation-zone lesion has a fundamentally different risk from a woman with a newly detected non-16/18 genotype and normal cytology.

**Artificial-intelligence-assisted cytology.** Conventional cervical cytology is effective but labor intensive. A single slide can contain tens of thousands of normal cells and only a small number of abnormal cells. Interpretation is influenced by staining quality, inflammation, blood, mucus, cell overlap, preparation artifacts, cytotechnologist fatigue, and observer experience. A large multicenter study published in 2025 developed a deep-learning model using whole-slide liquid-based cytology specimens from 17,397 women and evaluated it in 10,826 additional cases. Across nine hospitals, the system demonstrated robust generalization. In a multi-reader comparison, artificial-intelligence assistance increased sensitivity by approximately nine percentage points and reduced median interpretation time from 218 seconds to 30 seconds [5, 11, 16]. The clinically important feature of this approach is not autonomous replacement of the cytopathologist. The algorithm performs high-throughput prescreening, ranks suspicious regions, flags potentially abnormal cells, and allows the specialist to focus on diagnostically relevant areas. Artificial intelligence may also reduce false-negative results caused by rare abnormal cells. However, a system that maximizes sensitivity without calibrated specificity may refer too many women for colposcopy. Performance thresholds must therefore be selected according to the intended role: primary screening, HPV-positive triage, quality assurance, or diagnostic support [4, 7, 14].

**Table 1. Potential roles of artificial intelligence in cervical screening**

| Screening stage            | Artificial-intelligence function            | Expected clinical benefit                        | Principal risk                                        |
|----------------------------|---------------------------------------------|--------------------------------------------------|-------------------------------------------------------|
| Specimen collection        | Adequacy and quality assessment             | Earlier identification of insufficient samples   | Rejection of technically acceptable specimens         |
| Cytology prescreening      | Detection and ranking of abnormal cells     | Reduced workload and false-negative examinations | Excessive false-positive alerts                       |
| Whole-slide classification | Prediction of NILM, LSIL, HSIL, or cancer   | Standardized interpretation                      | Reduced performance after staining or scanner changes |
| HPV-positive triage        | Integration of genotype and morphology      | Fewer unnecessary colposcopies                   | Miscalibrated risk estimates                          |
| Colposcopy                 | Transformation-zone and lesion segmentation | Improved biopsy localization                     | Dependence on image quality                           |
| Follow-up                  | Prediction of persistence or progression    | Individualized surveillance intervals            | Inappropriate reassurance from uncertain predictions  |

**Compact microscopy and access in resource-limited settings.** High-performance slide scanners are expensive and require stable electricity, maintenance, data storage, and specialist technical support. These requirements limit digital cytology in many regions where cervical cancer mortality is greatest. A 2025 Nature Communications study combined a compact microscope costing approximately several hundred US dollars with an attention-transformer system. The model was trained and validated using 3,510 low-resolution slides from four hospitals and was subsequently evaluated on independent datasets. For detecting squamous intraepithelial lesions, reported external AUC values ranged from approximately 0.85 to 0.89, including an AUC of 0.85 in an HPV-positive subgroup [8, 9, 25]. This architecture is particularly relevant to decentralized

screening. Slides could be prepared and scanned in district facilities, while algorithmic triage identifies high-risk cases for referral to specialized centers. The model's weaker performance for subtle atypical squamous cells illustrates an important limitation. Low-cost imaging may be sufficient to identify overt high-grade abnormalities but may lose nuclear and chromatin detail required for borderline cytological interpretation [10, 13, 23].

**Automated colposcopy.** Colposcopy remains an essential diagnostic procedure for women with abnormal screening results. Its performance depends on complete visualization of the squamocolumnar junction, accurate recognition of acetowhitening, vascular patterns, lesion borders, iodine non-uptake, and selection of the most informative biopsy site. Interobserver variability is substantial, particularly for low-grade or small lesions. Artificial-intelligence systems can segment the cervix, identify the transformation zone, localize suspicious regions, and assign a probability of CIN2+. A multicenter retrospective validation of CerviCARE AI reported high sensitivity and specificity for identifying high-risk cervical lesions from digital cervicography images. Although promising, retrospective image classification does not prove that the system improves biopsy yield, reduces missed CIN3+, or changes cancer incidence [7, 8, 9]. The most useful interface would display a lesion heat map, transformation-zone boundary, confidence score, image-quality warning, and suggested biopsy areas. The colposcopist should retain final responsibility because inflammation, atrophy, pregnancy-related changes, previous treatment, scarring, and immature metaplasia can mimic precancer.

**Multimodal risk assessment.** No single test captures the complete biological pathway from HPV infection to invasive cancer. A multimodal model can integrate:

- HPV genotype and viral persistence;
- cytological class and cell-level morphology;
- colposcopic lesion characteristics;
- patient age and menopausal status;
- HIV infection or other immune suppression;
- previous CIN treatment;
- screening history;
- molecular biomarkers such as p16/Ki-67 or methylation markers.

Multimodal systems may outperform models based only on an isolated image because they combine viral, morphological, clinical, and longitudinal risk. However, more variables do not automatically produce better clinical decisions. Missing data, inconsistent coding, demographic bias, and overfitting can create an apparently accurate but poorly generalizable system [2, 3, 18].

**Table 2. Proposed prospective study of AI-supported HPV triage**

| Component           | Proposed specification                                                              |
|---------------------|-------------------------------------------------------------------------------------|
| Population          | Women with a positive high-risk HPV screening result                                |
| Design              | Prospective multicenter paired diagnostic-impact study                              |
| Index strategy      | AI integrating HPV genotype, cytology, colposcopy, age, and screening history       |
| Comparator          | Guideline-based conventional triage                                                 |
| Reference standard  | Histologically confirmed CIN2+, CIN3+, or invasive cancer                           |
| Primary endpoint    | Sensitivity for CIN3+ with reduction in unnecessary colposcopy                      |
| Secondary endpoints | CIN2+ detection, biopsy number, time to diagnosis, anxiety, cost, loss to follow-up |
| Safety endpoint     | Missed CIN3+ or invasive cancer within 24 months                                    |
| Calibration         | Reliability curves and observed risk within predicted-risk groups                   |
| Equity assessment   | Performance by age, ethnicity, HIV status, menopause, and clinical center           |
| External validation | Locked algorithm tested in countries not represented in model training              |

**Discussion.** The strongest contemporary evidence supports artificial intelligence as a clinical support tool rather than an independent diagnostic authority. In cytology, it can reduce the search burden, prioritize abnormal regions, and standardize classification. In colposcopy, it can identify the transformation zone and guide biopsy. In HPV-primary screening, it can combine several risk factors into a more individualized management recommendation. The greatest potential benefit may occur in healthcare systems with insufficient numbers of cytotechnologists, pathologists, and experienced colposcopists [15, 17, 27]. A low-cost scanner with a robust triage algorithm could extend screening coverage and prioritize referral of women at highest risk. Nevertheless, technological availability does not guarantee cancer prevention. A successful program also requires population invitation, sample collection, laboratory quality control, communication of results, colposcopy access, biopsy, treatment of precancer, cancer referral, and longitudinal follow-up. An accurate algorithm has little value when HPV-positive women are lost before treatment. External validation is the principal methodological requirement. Models trained in one country may perform differently in another because of variations in HPV prevalence, vaccination coverage, HIV prevalence, age distribution, cytology preparation, staining, camera equipment, and disease spectrum [6, 13, 28].

The very high accuracy reported in small public-image datasets should be interpreted cautiously. Randomly dividing images rather than patients can produce data leakage when images from the same woman appear in both training and testing sets. Prospective studies must separate datasets at the patient and institutional levels. The algorithm should be locked before evaluation, and histology should be assessed without knowledge of the AI result. Calibration is as important as discrimination. An algorithm may rank high-risk women correctly but still overestimate or underestimate their absolute risk [7, 14, 19]. Clinical decisions require probabilities that correspond to real-world outcomes. Artificial intelligence should also be allowed to abstain. When image quality is poor, the transformation zone is not visible, or the case lies outside the training distribution, the system should request repeat imaging or expert assessment rather than produce a falsely confident diagnosis. WHO's 2026 genotyping guidance provides an important framework for developing clinically coherent artificial-intelligence systems. Algorithms should complement validated HPV-based pathways rather than create isolated screening protocols disconnected from international recommendations [11, 12, 20].

**Conclusion.** Artificial intelligence is becoming an important component of modern cervical cancer prevention. Deep-learning-assisted cytology can improve abnormal-cell detection and reduce interpretation time. Compact digital microscopy may extend screening to resource-limited regions. Automated colposcopy can support transformation-zone assessment, lesion localization, and biopsy selection. The most promising strategy is a multimodal risk-based pathway combining HPV genotype, cytological morphology, colposcopic findings, patient characteristics, and screening history. Artificial intelligence should not replace HPV testing, histological confirmation, or clinical judgment. Its appropriate role is to improve triage, quality assurance, efficiency, and access. Before routine implementation, systems require prospective multicenter validation, accurate calibration, transparent uncertainty reporting, robust quality control, human oversight, cybersecurity, and continuous post-deployment monitoring. The final measure of success is not algorithmic accuracy. It is the safe detection and treatment of clinically significant precancer before invasive cervical cancer develops.

## References

1. World Health Organization. *WHO Guideline for Screening and Treatment of Cervical Pre-cancer Lesions for Cervical Cancer Prevention: Use of Human Papillomavirus DNA Genotyping*. Geneva: WHO; 2026.

2. World Health Organization. *Global Strategy to Accelerate the Elimination of Cervical Cancer as a Public Health Problem*. Geneva: WHO; 2020.
3. World Health Organization. Cervical cancer: fact sheet. Updated July 3, 2026.
4. Xue P, et al. Deep learning enabled liquid-based cytology model for cervical cancer screening and triage. *Nature Communications*. 2025;16. doi:10.1038/s41467-025-58883-3.
5. Bai J, Li N, Ye H, et al. AI-assisted cervical cytology precancerous screening for high-risk populations in resource-limited regions using a compact microscope. *Nature Communications*. 2025;16:7429. doi:10.1038/s41467-025-62589-x.
6. Ahmed SR, et al. Reproducible and clinically translatable deep neural networks for cervical screening. *Scientific Reports*. 2023;13. doi:10.1038/s41598-023-48721-1.
7. Ouh YT, et al. Development and validation of artificial intelligence-based analysis software to support screening of cervical intraepithelial neoplasia. *Scientific Reports*. 2024;14. doi:10.1038/s41598-024-51880-4.
8. Wu T, et al. Artificial-intelligence-based identification of the cervical transformation zone for colposcopy support. 2025.
9. Madathil S, et al. A multimodal deep-learning model for prediction of cervical intraepithelial neoplasia grade 2 or worse. *Computers in Biology and Medicine*. 2025.
10. International Agency for Research on Cancer. *Global Cancer Observatory: Cervix Uteri Fact Sheet*. Lyon: IARC; 2026.
11. de Sanjosé S, et al. Design of the HPV Automated Visual Evaluation study: validating a novel cervical-screening strategy. *eLife*. 2023;12.
12. World Health Organization. *WHO Guideline for Screening and Treatment of Cervical Pre-cancer Lesions for Cervical Cancer Prevention*. 2nd ed. Geneva: WHO; 2021.
13. World Health Organization. (2026). *WHO guideline for screening and treatment of cervical pre-cancer lesions for cervical cancer prevention: Use of human papillomavirus DNA genotyping*. World Health Organization.
14. Тер-Минасян, В. А. (2024). Возможности применения искусственного интеллекта в кольпоскопии в рамках скрининговых программ. *Онкология. Журнал имени П. А. Герцена*, 13(4), 66–71. doi:10.17116/onkolog20241304166.
15. Шарипова, И. П., Садирова, Ш. С., Рахимов, Р. А., Юлдашова, Г. Т., Шарапов, С. М., & Суяркулова, Д. Т. (2023). Результаты скрининга женщин на вирус папилломы человека. *Биология ва тиббиёт муаммолари*, 5(148), 245–250.
16. Xue, P., Dang, L., Kong, L. H., et al. (2025). Deep learning enabled liquid-based cytology model for cervical precancer and cancer detection. *Nature Communications*, 16, 3506. doi:10.1038/s41467-025-58883-3.
17. Пивазян, Л. Г., Унанян, А. Л., Давыдова, Ю. Д., Пойманова, О. Ф., Бондаренко, Е. Н., & Ищенко, А. И. (2022). Профилактика и скрининг рака шейки матки: обзор международных клинических рекомендаций. *Проблемы репродукции*, 28(5), 90–99. doi:10.17116/repro20222805190.
18. Захирова, Н. Н., Тиллашайхов, М. Н., Османова, Э. З., Ахмедов, О. М., Адылходжаев, А. А., & Сайдахмедова, В. А. (2021). Совершенствование ранней диагностики рака шейки матки на основе жидкостной цитологии и онкопротеина p53. *Доктор ахборотномаси*, 4(101), 116–122. doi:10.38095/2181-466X-20211014-116-122.
19. Bai, J., Li, N., Ye, H., Li, X., Chen, L., Hu, J., et al. (2025). AI-assisted cervical cytology precancerous screening for high-risk populations in resource-limited regions using a compact microscope. *Nature Communications*, 16, 7429. doi:10.1038/s41467-025-62589-x.
20. Клинышкова, Т. В. (2023). Стратегии цервикального скрининга: современный взгляд. *Российский вестник акушера-гинеколога*, 23(4), 20–26. doi:10.17116/rosakush20232304120.
21. Hu, L., Bell, D., Antani, S., Xue, Z., Yu, K., Horning, M. P., Gachuhi, N., Wilson, B., Jaiswal, M. S., Befano, B., Long, L. R., Herrero, R., Einstein, M. H., Burk, R. D., DeMarco, M., Gage, J. C., Rodriguez, A. C., Wentzensen, N., & Schiffman, M. (2019). An observational study of

deep learning and automated evaluation of cervical images for cancer screening. *Journal of the National Cancer Institute*, 111(9), 923–932. doi:10.1093/jnci/djy225.

22. Алиева, Д. А., Файзырахманова, М. М., & Мирзаева, Ю. К. (2022). Место скрининга в ликвидации рака шейки матки. *Доктор ахборотномаси*, 2.1(103), 29–32.

23. Wang, J., Yu, Y., Tan, Y., Wan, H., Zheng, N., He, Z., et al. (2024). Artificial intelligence enables precision diagnosis of cervical cytology grades and cervical cancer. *Nature Communications*, 15, 4369. doi:10.1038/s41467-024-48705-3.

24. Прилепская, В. Н. (2019). ВПЧ-ассоциированные заболевания шейки матки: скрининг, методы обследования, принципы лечения. *Гинекология*, 21(3), 6–8. doi:10.26442/20795696.2019.3.190595.

25. Ouh, Y. T., Kim, T. J., Ju, W., Kim, S. W., Jeon, S., Kim, S. N., Kim, K. G., & Lee, J. K. (2024). Development and validation of artificial intelligence-based analysis software to support screening system of cervical intraepithelial neoplasia. *Scientific Reports*, 14, 1957. doi:10.1038/s41598-024-51880-4.

26. Захирова, Н. Н., Атаханова, Н. Э., Ирисбаев, Б. К., & Гаппарова, Н. Н. (2010). Мониторинг женщин — носительниц вируса папилломы человека с фоновыми и предраковыми заболеваниями шейки матки. *Опухоли женской репродуктивной системы*, 1, 55–58.

27. Xue, P., Tang, C., Li, Q., Li, Y., Shen, Y., Zhao, Y., Chen, J., Wu, J., et al. (2020). Development and validation of an artificial intelligence system for grading colposcopic impressions and guiding biopsies. *BMC Medicine*, 18, 406. doi:10.1186/s12916-020-01860-y.

28. Министерство здравоохранения Российской Федерации. (2020). *Цервикальная интраэпителиальная неоплазия, эрозия и эктропион шейки матки: клинические рекомендации*. Министерство здравоохранения Российской Федерации.

29. Holmström, O., Linder, N., Kaingu, H., Mbuuko, N., Mbete, J., Kinyua, F., Törnquist, S., Muinde, M., Krogerus, L., Lundin, M., Diwan, V., & Lundin, J. (2021). Point-of-care digital cytology with artificial intelligence for cervical cancer screening in a resource-limited setting. *JAMA Network Open*, 4(3), e211740. doi:10.1001/jamanetworkopen.2021.1740.

30. Захирова, Н. Н., Тиллашайхов, М. Н., Адилхужаев, А. А., Ахмедов, О. М., Нишанов, Д. А., Османова, Э. З., & Сайдахмедова, В. А. (2022). Опыт реализации национальной программы вакцинации против вируса папилломы человека в Республике Узбекистан. *Журнал вестник врача*, 1(4), 24–29. doi:10.38095/2181-466X-20211014-23-28.

31. Xue, P., Wang, J., Qin, D., Yan, H., Qu, Y., Seery, S., Jiang, Y., & Qiao, Y. (2022). Deep learning in image-based breast and cervical cancer detection: A systematic review and meta-analysis. *npj Digital Medicine*, 5, 19. doi:10.1038/s41746-022-00559-z.

32. Bao, H., Bi, H., Zhang, X., Zhao, Y., Dong, Y., Luo, X., Zhou, D., et al. (2020). Artificial intelligence-assisted cytology for detection of cervical intraepithelial neoplasia or invasive cancer: A multicenter, clinical-based, observational study. *Gynecologic Oncology*, 159(1), 171–178. doi:10.1016/j.ygyno.2020.07.099.