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CERVICAL INTRAEPITHELIAL NEOPLASIA: MODERN DIAGNOSTIC METHODS AND THE ROLE OF ARTIFICIAL INTELLIGENCE

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Abstract. Cervical Cervical intraepithelial neoplasia (CIN) is a precancerous lesion of the cervical epithelium characterized by abnormal cell differentiation and proliferation. In most cases, the disease develops as a result of persistent infection with the human papillomavirus (HPV), particularly the highly oncogenic types 16 and 18.

Key words : cervical intraepithelial neoplasia, HPV, cytology, colposcopy , biomarkers , molecular diagnostics, liquid-based cytology, artificial intelligence.

Relevance . Early diagnosis of CIN is crucial for the prevention of cervical cancer, which remains one of the leading causes of cancer death in women. Modern technologies, including artificial intelligence (AI), can significantly improve the accuracy and effectiveness of diagnostics.

Objective . The aim of this study is to examine current diagnostic methods for cervical intraepithelial neoplasia (CIN) and to evaluate the role of artificial intelligence (AI) in improving the accuracy, objectivity, and effectiveness of detecting precancerous cervical changes.

Etiology and pathogenesis

The main cause of CIN development is long-term HPV infection. The virus integrates into the genome of epithelial cells, causing the expression of oncoproteins E6 and E7, which inhibit the tumor suppressors p53 and pRb . [3]

Risk factors include:

-early onset of sexual activity;

- frequent change of sexual partners;

-immunodeficiency states;

-smoking;

Modern diagnostic methods:

1. Clinical examination and anamnesis

The first stage includes a gynecological examination, assessment of complaints (bloody discharge, contact bleeding, pain, itching) and collection of anamnesis.

2. Cytological screening (PAP test) The PAP test (Papanicolaou test) remains the "gold standard" of CIN screening. It allows for the detection of atypical cells. Modern varieties include liquid-based cytology, which provides higher quality specimens and the possibility of subsequent HPV testing.[7]

3. HPV testing. Detection of DNA of highly oncogenic HPV types using PCR or hybrid capture (Hybrid Capture 2). The combined use of HPV testing and cytology (co-testing) increases the sensitivity of diagnosis. [4]

4. Colposcopy Extended colposcopy using acetic acid and Lugol's solution allows visualization of areas of atypical epithelium . Modern digital colposcopes with the ability to computerize images allow for an objective assessment of lesions. [6]

5. Histological examination (biopsy). This is the final method for confirming the diagnosis. The biopsy material is examined under a microscope to determine the degree of dysplasia of chronic inflammatory diseases of the genital tract. [9]

6. Molecular and immunohistochemical markers.
Key markers: p16 INK 4 a , Ki -67, TOP 2 A , MCM 2. They are used to differentiate true dysplasias from reactive changes. DNA methylation and gene expression analysis are also becoming important tools. [1,5,8]

Depending on the degree of damage, the following are distinguished:

CIN I - mild dysplasia limited to the lower third of the epithelium;

CIN II - moderate dysplasia (up to 2/3 of the epithelial thickness);

CIN III - severe dysplasia or carcinoma in situ (the entire thickness of the epithelium).

Materials and methods. Current approaches include:

- determination of biomarkers p16INK4a and Ki-67, reflecting the activity of cell proliferation;

- methylation of genes (eg, CADM1, MAL, miR-124-2) as an indicator of CIN progression;

-use of Next Generation Sequencing (NGS) for analysis of viral and cellular DNA.

These methods allow us to distinguish transient HPV infection from true neoplasia, which reduces overdiagnosis. The use of artificial intelligence in the diagnosis of CIN.

With the development of digital medicine, artificial intelligence has come to play a key role in image interpretation and data analysis.

1. AI in cytology. Machine learning algorithms analyze cell images, highlighting signs of atypia that humans miss . Application Convolutional neural networks (CNN) enable automatic classification of cells by degree of dysplasia with up to 95% accuracy. AI reduces the workload of cytologists and speeds up the screening process.

2. AI in colposcopy

Computer vision systems automatically evaluate colposcopic images, highlighting risk zones . For example, deep learning models identify CIN II–III with an accuracy comparable to human experts (approximately 90–94%). Platforms have emerged that integrate colposcopy , HPV testing, and AI analysis into a single diagnostic algorithm.

3. AI in histopathology

Neural networks are trained using digital microscopic images of histological specimens. AI can accurately determine the boundaries of a lesion, the level of dysplasia, and even predict the likelihood of progression to cancer.

4. AI and molecular diagnostics

Artificial intelligence is used to analyze massive data sets (multi-omics): gene expression, methylation, and protein profiles. This opens the way to personalized diagnostics and prognosis of CIN.

Advantages and limitations of using AI:

- increasing the sensitivity and specificity of diagnostics;

- reducing the subjectivity of medical assessment;

-acceleration of data analysis;

- possibility of remote consultations (telemedicine).

Restrictions:

- the need for large training samples;

-dependence on image quality;

- ethical and legal issues (responsibility for diagnosis).

Development prospects : The integration of AI with e-health systems will enable the creation of intelligent diagnostic platforms that combine clinical, laboratory, and imaging data . In the coming years, AI is expected to become the standard for CIN screening and monitoring, and will also aid in predicting the risk of malignancy.

Conclusion. Cervical Intraepithelial neoplasia remains a major issue in women's reproductive health. The use of modern diagnostic methods, particularly those based on artificial intelligence, significantly improves the effectiveness of disease detection and monitoring . The introduction of AI into clinical practice opens new opportunities for the early detection of precancerous conditions, personalized care, and reduction of cervical cancer mortality.

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