



REVIEW ARTICLE

HEMATOLOGIC INFLAMMATION IN OVARIAN CANCER: INTEGRATING ARTIFICIAL INTELLIGENCE AND BIOMARKERS FOR EARLY DETECTION

Emmanuel Ifeanyi Obeagu^{*1,2} , Venus Sunguro¹ 

¹Division of Haematology, Department of Biomedical and Laboratory Science, Africa University, Zimbabwe.

²Department of Molecular Medicine and Haematology, School of Pathology, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa.

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*Address for Correspondence:

Dr. Emmanuel Ifeanyi Obeagu, Department of Biomedical and Laboratory Science, Africa University, Zimbabwe, Tel: +263-778025658
 E-mail: emmanuelobeagu@yahoo.com

Abstract

Ovarian cancer continues to be a primary reason for gynecologic cancer deaths, primarily because of late diagnosis and the lack of effective screening methods. Hematologic inflammation, indicated by systemic markers like the neutrophil-to-lymphocyte ratio (NLR), platelet indices, and C-reactive protein, is crucial in the development and advancement of tumors. These readily obtainable inflammatory markers have demonstrated potential in forecasting disease presence and outcomes, but their clinical usefulness for early detection is still limited by low specificity and variability among patient groups. Recent developments in artificial intelligence (AI) present transformative opportunities to address these challenges by combining intricate biomarker data with clinical and imaging details. Machine learning algorithms can detect intricate, nonlinear trends in hematologic inflammation markers associated with early ovarian cancer, improving diagnostic precision over conventional techniques. This integration allows for tailored risk evaluation and ongoing monitoring, potentially allowing for earlier actions that enhance survival rates. This review examines the biological foundations of hematologic inflammation in ovarian cancer and assesses the developing role of AI-enhanced biomarker integration for early detection.

Keywords: Artificial intelligence, early detection, hematologic inflammation, biomarkers, ovarian cancer.

INTRODUCTION

Ovarian cancer continues to be one of the deadliest gynecologic cancers globally, standing as the fifth most common cause of cancer deaths in women. The elevated mortality rate can primarily be linked to the asymptomatic characteristics of the initial disease phase and the lack of effective screening methods, causing the majority of patients to be identified at later stages when treatment choices are restricted and outcomes are unfavorable¹. Timely identification is essential for enhancing survival rates, but existing diagnostic methods depend mainly on imaging and the CA-125 biomarker, which do not have adequate sensitivity and specificity for extensive screening². Chronic inflammation is progressively acknowledged as an essential factor in the development of numerous cancers, including ovarian cancer. The tumor micro-environment is defined by intricate interactions between cancerous cells and the immune and inflammatory systems of the host. Systemic hematologic inflammation, which can be accessed via standard blood tests, indicates the interaction between tumor and

host and has been linked to disease progression and response to treatment³. Biomarkers like the neutrophil-to-lymphocyte ratio (NLR), platelet levels, and platelet-to-lymphocyte ratio (PLR) act as indicators of systemic inflammation and immune function, positioning them as appealing options for non-invasive detection and prognosis of ovarian cancer⁴. Additionally, the diversity of ovarian cancer subtypes and the differences in host inflammatory responses complicate the interpretation and clinical relevance of these markers⁵. This requires the creation of sophisticated analytical tools capable of combining various biomarkers and clinical factors to enhance diagnostic precision⁶. AI and ML techniques have transformed medical data analysis by facilitating the extraction of significant patterns from extensive, multidimensional datasets. AI models are capable of examining intricate connections among hematologic inflammation indicators, clinical variables, and imaging information to create predictive algorithms for the early detection of ovarian cancer⁷. This integration has the potential to address the constraints of individual biomarkers and conventional statistical techniques,

enabling tailored risk evaluation and earlier detection⁸. Recent research utilizing AI on hematologic and clinical datasets has yielded encouraging outcomes, indicating enhanced sensitivity and specificity relative to traditional diagnostic methods. These developments may revolutionize ovarian cancer screening by facilitating dynamic, immediate risk categorization utilizing regularly gathered patient information⁹. Nevertheless, obstacles persist in model generalization, data consistency, and clinical application, especially considering the variety of patient groups and healthcare environments¹⁰.

This review aims to critically evaluate the role of hematologic inflammation markers in ovarian cancer and explore how artificial intelligence (AI) can be integrated with these biomarkers to enhance early detection.

METHODS

This narrative review was carried out via a thorough, non-systematic evaluation of the existing literature on hematologic inflammation in ovarian cancer, with a special focus on biomarker identification and analytical methods based on artificial intelligence. Articles that underwent peer review were located by searching major biomedical databases, including PubMed, Scopus, and Web of Science, using various combinations of keywords like ovarian cancer, hematologic inflammation, blood biomarkers, neutrophil-to-lymphocyte ratio, cytokines, machine learning, and artificial intelligence. Research articles, clinical trials, translational studies, and pertinent reviews published in English were emphasized, prioritizing studies with human participants and those demonstrating clear clinical or mechanistic significance. Only preclinical studies that offered essential understanding of inflammatory pathways or immune tumor interactions were included.

Retrieved articles were assessed for relevance according to title and abstract, and then underwent full-text evaluation. Evidence was qualitatively synthesized, concentrating on biological mechanisms, clinical correlations, and new technological applications instead of quantitative effect assessments. Specific focus was given to research that combines hematologic inflammatory markers with AI or machine learning

models for early detection, risk evaluation, or prognostic analysis. The results were woven together to present a consistent summary of existing understanding, emphasize methodological advantages and drawbacks, and pinpoint areas that need further exploration. Formal quality assessment and meta-analytic methods were not utilized, aligning with the narrative review approach.

Hematologic inflammation in ovarian cancer

Inflammation is crucial in the onset, advancement, and spread of ovarian cancer. The tumor microenvironment features a dynamic interaction between cancerous cells and the immune and inflammatory responses of the host. This engagement results in systemic alterations that can be quantified via hematologic inflammatory markers detectable in peripheral blood¹¹. These markers offer a non-invasive insight into the communication between the tumor and its host, positioning themselves as potential diagnostic and prognostic instruments in ovarian cancer¹². A highly researched marker of hematologic inflammation is the neutrophil-to-lymphocyte ratio (NLR). Neutrophils play a role in tumor advancement by secreting pro-inflammatory cytokines, reactive oxygen species, and angiogenic factors like vascular endothelial growth factor (VEGF), which aid in tumor growth and metastasis. In contrast, lymphocytes, especially cytotoxic T cells, are essential for anti-tumor immunity by identifying and destroying cancerous cells. An elevated NLR, showing a rise in neutrophils and a drop in lymphocytes, signifies an immunosuppressive and pro-tumor inflammatory condition and has been consistently linked to advanced tumor stages, suboptimal chemotherapy responses, and diminished overall survival in ovarian cancer patients¹³⁻¹⁵.

Platelets play a crucial role in inflammation and progression related to cancer. In addition to their traditional function in hemostasis, platelets release growth factors, cytokines, and chemokines that promote tumor cell viability, angiogenesis, and metastasis. Higher platelet counts and a greater platelet-to-lymphocyte ratio (PLR) have been associated with aggressive tumor characteristics and worse clinical outcomes in ovarian cancer. Platelets can protect circulating tumor cells from immune attack and facilitate their attachment to the endothelium, thereby increasing metastatic capability¹⁶⁻¹⁸.

Table 1: Common hematologic inflammation biomarkers in ovarian cancer.

Biomarker		Description	Clinical Significance	Limitations
Neutrophil-to-Lymphocyte (NLR)	Ratio	Ratio of neutrophils to lymphocytes in blood	Reflects systemic inflammation and immunosuppression; linked to prognosis and disease progression	Affected by infections, comorbidities, non-specific
Platelet-to-Lymphocyte (PLR)	Ratio	Ratio of platelets to lymphocytes	Indicates pro-tumor platelet activity and immune status; associated with tumor aggressiveness	Variable across subtypes and physiological conditions
C-Reactive Protein (CRP)	Protein	Acute phase protein, marker of systemic inflammation	Correlates with tumor burden and prognosis	Non-specific; influenced by infections and chronic inflammation
Erythrocyte Sedimentation (ESR)	Rate	Rate of red blood cell sedimentation	Reflects chronic inflammation	Low specificity; affected by anemia, other diseases
Mean Platelet Volume (MPV)	Platelet	Average size of platelets	May indicate platelet activation related to cancer progression	Limited data; requires standardization

Other inflammatory indicators, including C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR), represent systemic inflammation and have shown associations with tumor load and outlook¹⁹. Nonetheless, their clinical usefulness is constrained by insufficient specificity and vulnerability to confounding factors like infections and chronic inflammatory disorders. Integrating various hematologic markers into composite indices could enhance predictive precision by reflecting different aspects of the inflammatory response (Table 1)²⁰.

Artificial intelligence in biomarker integration and early detection

Artificial intelligence (AI), including machine learning (ML) and deep learning approaches, has quickly changed the realm of biomedical research and clinical diagnostics. Its ability to process substantial, intricate, and multidimensional datasets makes AI particularly well-equipped for combining diverse biomarker data to enhance disease identification, prognosis, and treatment strategies. In ovarian cancer, known for its difficult early diagnosis, AI-based methods present hopeful strategies for utilizing hematologic inflammation markers together with clinical and imaging data to improve the precision of early detection^{21,22}. Conventional statistical techniques frequently neglect to identify nonlinear connections and subtle interactions among various biomarkers and patient traits. Algorithms in machine learning like support vector

machines, random forests, and neural networks can represent these intricate relationships by learning from extensive datasets to differentiate between malignant and benign or healthy conditions²³. For instance, the combination of hematologic inflammation indicators such as neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and C-reactive protein (CRP) with demographic and clinical factors facilitates the creation of strong predictive models that exceed the performance of analyses based on individual markers²⁴. Additionally, AI can integrate radiomic characteristics derived from ultrasound, CT, or MRI scans to enhance blood-based biomarkers, offering a multimodal strategy for the early detection of ovarian cancer. Radiomics measures tumor variability and micro-environment features linked to fundamental inflammatory activities. AI algorithms can combine these varied data types into risk scores or diagnostic classifiers, enabling flexible, individualized evaluations^{25,26}. Extensive, carefully organized datasets are essential for training and validating AI models. Collaborative partnerships and data-sharing efforts can hasten this process by offering varied, annotated patient groups that capture real-world diversity²⁷. Moreover, future clinical trials are essential to prove the effectiveness and safety of AI-based biomarker integration tools prior to their extensive use in clinical settings (Table 2)²⁸.

Table 2: Applications of artificial intelligence in ovarian cancer early detection.

AI Technique	Data type integrated	Key advantages	Challenges
Machine Learning (Random Forest, SVM)	Hematologic markers + clinical data	Handles nonlinear relationships; improves risk stratification	Requires large datasets; overfitting risk
Deep Learning (Neural Networks)	Multi-omics + imaging + blood biomarkers	High predictive power; extracts complex features	Computationally intensive; interpretability issues
Radiomics + AI	Imaging data combined with biomarkers	Quantifies tumor heterogeneity; multimodal integration	Standardization of imaging protocols
Explainable AI (XAI)	All of the above	Improves transparency and clinician trust	Early-stage development; needs validation

Current Challenges

Even with notable progress in comprehending the role of hematologic inflammation and the potential of artificial intelligence (AI) in detecting ovarian cancer, various obstacles hinder the application of these findings in everyday clinical practice. A primary challenge is the natural biological variability of inflammatory biomarkers. Hematologic indicators like neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and C-reactive protein (CRP) are affected by numerous factors not connected to cancer, such as infections, autoimmune disorders, medications, and physiological stress²⁹. The absence of specificity hinders the creation of clear diagnostic thresholds and can result in both false-positive and false-negative outcomes in ovarian cancer screening³⁰. A significant challenge stems from the diversity of ovarian cancer itself. The condition includes various histologic subtypes characterized by unique molecular profiles and inflammatory signatures. This variety requires biomarker panels and AI models capable of handling subtype-specific patterns, which heightens the

complexity of data integration and model creation. Furthermore, factors related to patients, including age, comorbidities, and lifestyle, also impact markers of hematologic inflammation, necessitating careful attention when developing predictive algorithms³¹.

From a technical perspective, the creation and verification of AI models encounter substantial challenges. Large-scale datasets of high quality with detailed clinical annotations are crucial for developing strong algorithms; nonetheless, these datasets are frequently limited, fragmented, or constrained by patient privacy laws. Differences in laboratory measurement methods and imaging protocols among institutions further diminish the reproducibility and generalizability of AI models. Furthermore, the “black box” characteristic of various AI methods restricts interpretability, hindering clinicians' trust and acceptance of these tools without transparent explanations of the decision-making processes^{32,33}. Incorporating AI systems into current clinical workflows brings logistical and ethical issues. Prioritizing data protection, patient confidentiality, and adherence to

regulations is crucial. Interdisciplinary collaboration among oncologists, data scientists, and healthcare administrators is essential to create intuitive platforms that enhance clinical decision-making without adding complexity. Additionally, tackling possible biases in AI models stemming from uneven training datasets is essential to prevent inequalities in care³⁴. Although retrospective studies have shown encouraging out-

comes, prospective validation across varied populations is still sparse. Strenuous clinical trials are essential to assess the genuine effectiveness, safety, and cost-effectiveness of AI-improved bio-marker screening. In the absence of such evidence, obtaining regulatory approval and gaining clinical acceptance could be obstructed (Table 3)³⁵.

Table 3: Challenges and future directions in ai-integrated hematologic biomarker research.

Challenge	Description	Proposed solutions	Impact on clinical practice
Biomarker Variability	Influenced by infections, comorbidities, physiological factors	Standardize assays; incorporate clinical context	Improves biomarker reliability and specificity
Ovarian Cancer Heterogeneity	Diverse tumor subtypes with different inflammatory profiles	Subtype-specific biomarker panels and AI models	Enables personalized risk assessment
Data Quality and Quantity	Limited large, annotated datasets for training AI	Collaborative consortia; data sharing; multicenter studies	Enhances model robustness and generalizability
AI Model Interpretability	Black-box nature limits clinical trust	Develop explainable AI frameworks	Facilitates clinical adoption
Ethical and Regulatory Issues	Patient privacy, data security, and bias concerns	Implement strict data governance; bias mitigation strategies	Ensures equitable, ethical AI use
Clinical Integration	Workflow disruption and user-friendliness	User-centric design; clinician involvement	Streamlines implementation and improves uptake
Prospective Validation	Lack of large-scale clinical trials	Conduct multicenter, prospective studies	Provides evidence for regulatory approval

Future Perspectives

Combining hematologic inflammation indicators with artificial intelligence (AI) signals a new phase in the early detection of ovarian cancer, but achieving this potential will necessitate ongoing innovation and teamwork across various disciplines. A promising avenue is the enhancement of multiomics strategies that integrate genomic, transcriptomic, proteomic, metabolomic, and epigenomic information along with hematologic and clinical metrics. This extensive profiling can map the complex biological features of ovarian cancer and its systemic impacts, allowing AI models to pinpoint more accurate and personalized biomarkers for early detection of the disease³⁶. Progress in AI, especially regarding explainable AI (XAI) methods, will be vital in connecting algorithmic forecasts with clinical understanding. By offering clear and comprehensible decision-making methodologies, XAI can enhance clinician confidence and promote the use of AI-supported diagnostic instruments. Moreover, AI models that consistently learn from real-world data, integrating ongoing patient monitoring and treatment outcomes, will facilitate adaptive risk evaluation and prompt clinical actions³⁷.

Standardizing hematologic biomarker measurements and clinical data collection methods across institutions is crucial for enhancing the reproducibility and generalizability of AI models. Creating extensive, varied, and thoroughly annotated datasets via global collaborations and data-sharing programs will speed up model training, testing, and improvement. Addressing ethical issues, such as patient privacy, data security, and algorithmic bias, must stay at the forefront of these advancements to guarantee equitable access and confidence in AI-based healthcare solutions³⁸. New technologies like point-of-care testing and wearable

biosensors provide further chances to incorporate continuous monitoring of inflammatory markers into standard care. Integrating these technologies with AI analytics may allow for real-time monitoring of ovarian cancer risk, particularly in populations at high risk. In addition, integrating AI-enhanced imaging techniques with hematologic biomarkers creates a multimodal diagnostic system that boosts the precision of early detection³⁹. The clinical application will necessitate future trials to assess AI-enhanced biomarker panels across varied patient groups, examining not only diagnostic efficacy but also effects on clinical choices, patient results, and healthcare expenditures. Working together, clinicians, data scientists, regulatory bodies, and industry participants will be essential for transforming research breakthroughs into verified, accessible tools integrated into clinical practices⁴⁰.

CONCLUSIONS

Hematologic inflammation markers offer a valuable, minimally invasive window into the tumor-host interactions that characterize ovarian cancer. While individual inflammatory biomarkers such as neutrophil-to-lymphocyte ratio and platelet indices have demonstrated prognostic significance, their diagnostic utility for early detection is limited by biological variability and lack of specificity. Integrating these markers with clinical and imaging data through artificial intelligence (AI) represents a promising approach to overcome these challenges, enabling the identification of subtle, complex patterns indicative of early ovarian malignancy. AI-driven models have the potential to transform ovarian cancer screening by improving sensitivity and specificity, facilitating personalized risk stratification, and supporting timely

clinical decision-making. However, the widespread adoption of these technologies requires overcoming obstacles related to data heterogeneity, model interpretability, and ethical considerations. Collaborative efforts to standardize biomarker assessment, develop explainable AI algorithms, and validate predictive models in diverse populations are essential to ensure clinical applicability and equity.

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AUTHOR'S CONTRIBUTION

Obeagu EI: conceived the idea, writing the manuscript, literature survey. **Sunguro V:** formal analysis, data processing. Final manuscript was checked and approved by both authors.

DATA AVAILABILITY

The empirical data used to support the study's conclusions are available upon request from the corresponding author.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

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