

Advances and Prospects of Artificial Intelligence in the Diagnosis and Management of Ovarian Cancer

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Abstract

Ovarian cancer (OC), the most fatal gynecologic malignancy worldwide, is predicted to show rising trends in both incidence and mortality over the coming years. Late-stage presentation, limitations in currently available therapeutic approaches, and poor response in advanced disease are major contributors to unfavorable outcomes in these patients. Artificial intelligence (AI), in its various forms, has evolved in recent years into a revolutionary strategy with remarkable potential across different aspects of OC management. This narrative review is based on recently published peer-reviewed studies (2019–2025) identified through PubMed, Scopus, and Web of Science, with a focus on the diagnostic, prognostic, and therapeutic applications of AI in ovarian cancer. Studies suggest that AI models can equal, and in many cases surpass, human experts' capabilities in cancer diagnosis and characterization. Medical image analysis using machine learning (ML) algorithms has shown exceptional performance, while deep learning (DL) models have been able to discriminate benign from malignant ovarian tumors with notable accuracy. Furthermore, AI-derived biomarkers provide noninvasive tools for screening and prognostication. Natural language processing (NLP) extracts valuable insights from clinical data to predict treatment outcomes, while ML integrates multi-omics data to optimize therapeutic regimens and surgical outcomes. AI models can also predict drug resistance, assist in identifying therapeutic targets, and help optimize treatment combinations. This comprehensive integration of AI technologies promises to transform OC care from late-stage intervention to early detection, precision prognostication, and personalized treatment strategies, offering renewed hope for improving patient outcomes in this challenging disease.

Keywords: Ovarian Cancer; Artificial Intelligence; Machine Learning; Deep Learning; Precision Oncology.

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Introduction

Ovarian cancer (OC), ranking eighth worldwide in both incidence and cancer-related mortality among women (*Ovarian Cancer Statistics | World Cancer Research Fund*, n.d.), comprises multiple subtypes, with high-grade serous carcinoma being the most common and most aggressive subtype (Kurman & Shih, 2010). Global epidemiologic projections indicate that both the incidence and mortality of OC are expected to rise in the coming decades, particularly in low- and middle-income countries, mainly because of population aging, lifestyle and environmental changes, and limited access to optimal treatment options in these settings (Stewart et al., 2019). Owing to the often asymptomatic nature of disease progression and the lack of effective screening modalities, 5-year survival rates remain low despite recent advances in the detection and treatment of OC (*Ovarian Cancer Statistics | World Cancer Research Fund*, n.d.). Artificial intelligence (AI) has shown considerable potential to improve outcomes for these patients by helping identify patterns in imaging, histopathology, genomics, and electronic health records (EHRs). Several AI modalities have been utilized in ovarian cancer, including machine learning (ML), deep learning (DL), natural language processing (NLP), radiomics, computer vision, and clinical decision support systems (CDSS)/expert systems (ES). Although these modalities share certain operational concepts, each has distinct applications and offers unique clinical contributions (Esteva et al., 2019). ML and DL are computational learning approaches that can be applied to both structured and unstructured data. However, DL is particularly well suited to the analysis of high-dimensional unstructured data, such as medical images and genomic profiles (Erickson et al., 2017; Esteva et al., 2019). These clinical challenges, particularly late-stage detection and limited prognostic precision, highlight the need for innovative solutions. AI directly addresses these gaps by enhancing early detection through imaging and liquid biopsy, improving prognostication through multi-omics integration, and supporting treatment optimization in ways that conventional methods have struggled to achieve. NLP is commonly used to derive meaning from unstructured human language, including clinical text such as EHRs and pathology reports (Jiang et al., 2017). In contrast, radiomics and computer vision focus on domain-specific visual data, including CT, MRI, and histopathology images, to support diagnostic and prognostic tasks (Lambin et al., 2012; Skrede et al., 2020). CDSS and ES use structured clinical data to define rules, patterns, or learned models for treatment planning and clinical assessment (Shortliffe & Sepúlveda, 2018; Topol, 2019). The application of AI in oncology has substantially changed how data are interpreted and how patients are selected for targeted therapies. The use of AI in OC has shown promise in

advancing precision medicine, improving the prediction of treatment outcomes, and increasing the accuracy of diagnostic tools.

Early Detection of Ovarian Cancers

Early detection remains one of the greatest challenges in ovarian cancer because symptoms are often nonspecific and many patients present with advanced-stage disease. Recent advances in AI have created new opportunities to improve early diagnosis through blood-based biomarkers, liquid biopsy approaches, and imaging-based classification systems.

Blood-Based Diagnostics

An AI-driven blood test developed by researchers at Georgia Tech, which analyzes metabolite profiles, demonstrated a diagnostic accuracy of 93% for ovarian cancer, particularly among women who had been clinically categorized as normal (Ban et al., 2024). Another study conducted in Chinese women showed that an AI-based multicriteria decision-making classification fusion model offers a low-cost, accessible, and accurate diagnostic tool for ovarian cancer (G. Cai et al., 2024).

Liquid Biopsy and Fragmentomics

By detecting genome-wide fragmentation patterns suggestive of malignancy, the DELFI technique, which uses AI to examine cell-free DNA fragment patterns in blood, enabled the noninvasive identification of ovarian cancer with good accuracy (AUC = 0.88) (Medina et al., 2025).

Ultrasound Imaging

A landmark 2025 study involving 17,378 ultrasound images from 3,652 patients across 20 hospitals in eight countries demonstrated that AI models achieved an accuracy of 86.3% in differentiating benign from malignant ovarian lesions, outperforming both expert (82.6%) and nonexpert (77.7%) examiners (Christiansen et al., 2025). Another study using neural networks trained on transvaginal ultrasound images of epithelial ovarian cancers reported sensitivity and specificity values exceeding 90% for the detection of early-stage epithelial ovarian cancers (Christiansen et al., 2021).

AI in Diagnostic Imaging

AI-based imaging techniques have substantially improved the accuracy of ovarian cancer detection. A recent study reported promising performance for detecting OC using ultrasound images, with 81% sensitivity and 92% specificity (Mitchell et al., 2024). Furthermore, convolutional neural networks (CNNs) and other deep learning models have demonstrated strong diagnostic performance on CT and MRI scans. These models were comparable to expert radiologists in

distinguishing epithelial ovarian carcinomas from other pelvic tumors, with area under the curve (AUC) values ranging from 0.87 to 0.92 (He et al., 2024). In addition, a CT-based AI model showed potential for accurate preoperative staging of OC by predicting omental and peritoneal involvement; a deep learning radiomic nomogram demonstrated promising performance, with AUCs of 0.943 and 0.951 for preoperative prediction (Liu et al., 2025). Compared with conventional diagnostic approaches, such as expert ultrasound interpretation, serum CA-125 testing, or traditional radiologic staging, AI-based tools demonstrate clear incremental value. For example, AI models achieve higher sensitivity and specificity in differentiating benign from malignant lesions than experienced radiologists, while also offering reproducibility and scalability. Similarly, AI-enhanced CT and MRI analyses may outperform standard radiographic evaluation by identifying subtle imaging biomarkers not readily visible to the human eye, thereby improving diagnostic confidence and staging accuracy. These findings further support the potential of AI tools to enhance diagnostic confidence and improve clinical decision-making and treatment planning.

Histopathological Subtyping and Genomic Analysis

The integration of AI models has substantially supported histopathological assessment through their ability to classify OC subtypes. Automated cancer subtype classification and grading can now be performed with the aid of DL algorithms on whole-slide images (WSIs), showing concordance rates exceeding 80% with expert pathologists (Ueda et al., 2024). Transformer-based AI models have also been used to classify OC histological subtypes, such as high-grade serous, clear cell, and endometrioid tumors, with balanced accuracies surpassing 90% even on external datasets in a comprehensive benchmarking study conducted in 2024 using WSIs (Breen et al., 2025). In addition, the integration of next-generation sequencing (NGS) data for the molecular categorization of OC has shown promising potential. AI-derived genomic models can stratify patients for targeted therapeutic approaches and may confer a survival advantage through more precise treatment selection. A novel approach combining methylation, somatic mutation, and gene expression data demonstrated promising performance in predicting personalized therapy response and supporting precision management in OC patients (Mallya et al., 2025).

Prognostication and Risk Stratification

Prognostication Based on Electronic Health Reports (EHRs)

AI is assuming an increasingly important role in the prognostication and risk stratification of OC through

its ability to analyze large volumes of EHR data that often remain underused. ML- and NLP-enabled systems can process structured, semi-structured, and unstructured data, including demographic information, pathology reports, laboratory results, treatment histories, and clinical notes, to identify patterns associated with patient outcomes. These tools may offer greater precision than traditional approaches in predicting overall survival (OS), risk of recurrence, response to therapy, and risk stratification across patient groups (Rajkomar et al., 2019; Senders et al., 2018). For example, DL algorithms trained on EHR data have outperformed static risk models by capturing real-world variability and longitudinal patterns over time that conventional models often overlook, thereby offering clinically valuable predictive insights (Miotto et al., 2016). In addition, NLP can be used to extract meaningful information from free-text records, such as comorbidity details and symptom burden, to identify prognostic factors and support risk stratification (Koleck et al., 2019). Such AI-empowered models may enable clinicians to tailor treatment recommendations and follow-up strategies, potentially improving patient outcomes while reducing unnecessary resource utilization.

Prognostication Based on Biomarkers

The ability of AI to analyze blood-based biomarkers has opened the door to noninvasive prognostic prediction. Several ML models based on preoperative blood factors have achieved an AUC of 0.968 in distinguishing benign from malignant ovarian tumors (Kawakami et al., 2019). In addition, AI-assisted analyses of circulating white blood cells have shown potential for predicting survival in serous OC (Feng et al., 2022). In high-grade serous OC, an AI model developed using clinical, genomic, and pathological data has been shown to accurately predict both overall and progression-free survival. This approach, which incorporates the genomic instability index derived from sequencing data together with tumor microenvironment parameters from digital histopathology, outperformed traditional Cox regression models in both discrimination and calibration (Bi et al., 2025). Another study using DL on CT-radiomics data identified predictive imaging biomarkers and stratified patients into high- and low-risk groups, with an accuracy of 88.4% for predicting 3-year recurrence rates (Wei et al., 2019). Moreover, a multi-omics approach integrating transcriptomic and proteomic data with ML algorithms identified immune-relevant signals, including tumor-infiltrating lymphocytes (TILs) and PD-L1 expression. These features were associated with longer survival and better response to platinum-based chemotherapy (Jiao et al., 2024). Collectively, these findings support the role of AI in uncovering subtle clinical and biological signals that may improve prognostic assessment and

optimize clinical decision-making for patients with OC. Beyond the performance of individual modalities, future clinical workflows will likely depend on the integration of multiple AI approaches. Combining radiomics with liquid-biopsy fragmentomics, or incorporating genomic and transcriptomic signals alongside imaging features, could provide a more comprehensive stratification strategy that captures tumor biology, host response, and anatomical spread simultaneously. Such multilayered integration would better reflect real-world patient management and enhance the practical applicability of AI in ovarian cancer care.

Surgical Management of OC

AI Surgical Planning and Robotic Assistance

Preoperative evaluation supported by AI-assisted surgical navigation may improve tumor debulking strategies, resulting in better surgical outcomes and higher rates of optimal cytoreduction. In a prospective study comparing preoperative CT imaging and clinical characteristics, gynecologic oncologists were able to use AI algorithms to identify the most suitable candidates for debulking surgery rather than neoadjuvant chemotherapy (NACT), with high accuracy in predicting complete cytoreduction (Yin et al., 2023). In addition, surgical-planning tools enhanced by AI-driven three-dimensional mapping technologies have enabled more precise visualization of tumor extension and invasion of critical structures. This has improved intraoperative navigation and has been associated with reductions in operative time and blood loss compared with standard planning (Z. Cai et al., 2024). Lower complication rates and greater consistency in dissection techniques during OC cytoreduction have also been attributed to the use of real-time AI systems in robot-assisted procedures, which can assess operative performance and generate alerts when procedural deviations occur (Carbajal-Mamani et al., 2020). These examples illustrate how AI is transforming surgery by improving planning accuracy, facilitating minimally invasive approaches, and supporting dynamic intraoperative decision-making.

Surgical Outcomes Prediction

Therapeutic planning in OC depends heavily on the ability to predict surgical outcomes. AI models have shown considerable potential in surgical decision-making, often outperforming traditional statistical methods. Because complete cytoreduction remains the strongest prognostic factor in advanced OC, accurate preoperative risk stratification is essential. In a multicenter prospective trial (Suidan et al., 2014), preoperative CT findings and serum CA-125 were shown to be valuable in predicting suboptimal cytoreduction at primary debulking surgery. More

recently, ML models incorporating clinical data, CA-125 values, radiomic features derived from CT scans, and patient comorbidities have shown promising ability to predict the likelihood of poor cytoreduction. In a systematic review of 10 trials involving 3,460 patients, AI models predicted overall survival and complete cytoreduction with accuracies of 69.6% and 80.5%, respectively (Noei Teymoordash et al., 2025). Other studies have used intraoperative and preoperative data to predict postoperative overall morbidity. AI models assisted surgeons in resource allocation and perioperative management planning by using patient-related factors such as age, body mass index, and comorbidity index, along with tumor-related factors including preoperative CA-125 and malignancy scores, to predict adverse surgical outcomes such as ICU admission, prolonged hospital stay, and urinary tract infection with high accuracy (Laios et al., 2021; Laios, Kalampokis, et al., 2022; Yi et al., 2021). Furthermore, explainable AI architectures have begun to clarify these predictions by identifying key determinants, such as patterns of tumor spread and ascites volume, as predictors of adverse surgical outcomes (Laios, De Freitas, et al., 2022). These AI-based applications may improve surgical decision-making and facilitate more individualized treatment planning, potentially improving survival while reducing unnecessary surgical risk.

Response Prediction and Treatment Optimization

AI has enabled more personalized treatment approaches and has become increasingly important in predicting therapeutic response and optimizing treatment strategies for OC. Response to the antiangiogenic agent bevacizumab in patients with high-grade serous OC has been predicted using DL-based models applied to histopathological whole-slide images. In this context, the AI model achieved an AUC of 0.86, outperforming models based solely on conventional clinical features (Mallya et al., 2025). An AI-integrated multi-omics system has also shown promise in informing patient stratification for immunotherapy by combining gene expression, proteomic, and mutation data while generating personalized counterfactual treatment recommendations (Maiorano et al., 2025). In another study, radiomics-derived signals from CT imaging achieved prediction accuracies exceeding 90% for platinum sensitivity, enabling clinicians to classify patients as responders or nonresponders before treatment initiation (G. Cai et al., 2024). The integration of radiogenomic and clinicopathologic data into a single model demonstrated even higher performance for predicting chemotherapy resistance, with an AUC of 0.993 (Bi et al., 2025). Another important frontier involves the use of AI for drug repurposing and the

identification of novel therapeutic targets. This strategy uses proteomic, genomic, and metabolic signatures of cancer cells to predict which drugs are most likely to act against specific targets, particularly in resistant subtypes (Villegas-Vazquez et al., 2025; Weth et al., 2024). Together, these developments illustrate how AI supports precision oncology by reducing exposure to ineffective therapies, improving treatment selection, and enabling more accurate prediction of treatment response.

Challenges and Future Directions

Despite the rapid evolution of AI-derived diagnostic, prognostic, and predictive tools, several barriers continue to limit their routine application in OC care. Generalizability remains a major concern because many models have been trained on overly homogeneous datasets that do not adequately capture regional, ethnic, or histologic variability, thereby increasing the risk of bias and limiting clinical utility (Suidan et al., 2014). Another common reason for poor external validation is overfitting to training data or insufficient model robustness when applied to larger external datasets or to settings with minor differences in data representation (Beam & Kohane, 2018). In addition, current models often rely on historical data and therefore require regular recalibration to account for temporal drift and evolving clinical trends (Ghassemi et al., 2020). Predictions may also be distorted by hidden biases related to unequal representation across patient groups and disease stages during model development (Obermeyer et al., 2019). Moreover, ethical and regulatory concerns must be addressed, particularly those related to transparency, data protection, and the need for prospective clinical validation before widespread implementation (Topol, 2019). Interpretable AI systems that generate clinically meaningful results are essential for building clinician trust and accountability in high-stakes oncology decision-making (Senders et al., 2018). One promising future strategy is the development of federated learning models, which allow AI systems to be trained on diverse datasets without compromising patient privacy. This approach is already being explored in multi-institutional health datasets (Rieke et al., 2020). In addition, AI-based real-time CDSS that continuously evolve with new clinical evidence may provide future tools for more refined precision therapy and surveillance strategies (Elhaddad & Hamam, 2024). This balance between enthusiasm for AI and recognition of its limitations underscores the need for rigorous validation, ethical oversight, and close clinician–AI collaboration if these technologies are to be successfully translated into routine OC care. Concrete examples illustrate these barriers: the absence of FDA- or EMA-approved AI diagnostic tools in ovarian cancer has delayed clinical translation; strict data-protection frameworks such as

GDPR and HIPAA restrict cross-institutional data sharing that is critical for model training; and prior reports of algorithmic bias in oncology have raised concerns about patient safety and equity, further slowing adoption. These regulatory and ethical barriers highlight the importance of transparent validation pathways and prospective trials before widespread implementation.

Conclusion

AI carries substantial potential to revolutionize OC care across the entire care continuum. It may improve and personalize patient outcomes at multiple stages, including detection, risk stratification, surgical planning, treatment selection, response assessment, and survival prediction. The incorporation of different AI models into gynecologic oncology practice will require continued research, validation, standardization, and cross-disciplinary collaboration. Consistent interdisciplinary cooperation among physicians, data scientists, engineers, and healthcare administrators will help ensure that technological advances remain aligned with clinical needs, ethical standards, and practical workflows. Future research should prioritize multi-institutional and prospective clinical trials to validate AI models across diverse populations. Establishing standardized reporting frameworks, including transparent AI performance metrics, and aligning implementation with regulatory requirements will be crucial for widespread adoption. These steps will help ensure that advances in AI move beyond proof-of-concept studies and into routine ovarian cancer care, thereby maximizing their potential to improve patient outcomes.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for Publication

Not applicable.

Availability of Data and Material

No new data was generated or analyzed in this study.

Conflicts of Interest / Competing Interests

The authors declare that there are no conflicts of interest.

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Authors' Contributions

J.M.A: Conceptualization, Methodology, Writing of the original draft, Writing – review & editing, Visualization.

S.M.A: Software, Validation, Writing – review & editing, Visualization, Project administration, Supervision.

S.A.M: Formal analysis, Resources, Writing – review & editing, Supervision.

R.Q.A: Formal analysis, Data curation, Writing – review & editing, Project administration.

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Use of Generative AI and AI-Assisted Technologies

The authors declare that no generative AI or AI-assisted technologies were used in the preparation of this work.

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