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Review

Artificial Intelligence in Gynecologic Cancer: A Review of Applications and Advancements

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Abstract

Gynecologic cancers, including cervical, ovarian, endometrial, vaginal, and vulvar malignancies, remain a major global health burden, accounting for substantial morbidity and mortality among women. Despite advances in conventional treatments such as surgery, chemotherapy, and radiotherapy, survival outcomes remain suboptimal, particularly in cases diagnosed at advanced stages. In recent years, artificial intelligence (AI) has emerged as a transformative tool in gynecologic oncology, offering novel approaches to enhance diagnostic accuracy, stratify risk, personalize treatment strategies, and streamline clinical workflows. This narrative review provides a comprehensive overview of the current and emerging applications of AI in the management of gynecologic cancers. Key developments are discussed, including deep learning models for imaging interpretation, AI-driven biomarker analysis for early detection, and predictive algorithms for assessing treatment response and toxicity risk. Additionally, the use of AI in automating cytopathology and optimizing resource allocation is explored. While early findings are promising, challenges remain regarding the generalizability of AI models across diverse populations, the need for standardized datasets, and the integration of AI tools into routine clinical practice. Addressing these limitations is essential to ensure safe, equitable, and effective implementation. Overall, this review underscores the potential of AI to significantly improve patient outcomes and clinical efficiency in gynecologic oncology. Future research and interdisciplinary collaboration will be critical in translating these innovations into real-world clinical benefit.

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1. INTRODUCTION

Cancers of the female reproductive tract encompass multiple malignancies, such as ovarian, cervical, uterine, vaginal, and vulvar cancers (1, 2). Globally, these diseases represent a major public health challenge, with roughly 1.3 million new diagnoses and 500 000 deaths each year (3). The elevated mortality is largely due to late-stage detection, emphasizing the critical need for earlier diagnosis and intervention (4). Standard treatment regimens for gynecologic malignancies typically involve a combination of surgery, chemotherapy, and radiotherapy. Notably, brachytherapy, when combined with external beam radiation therapy (EBRT) and chemotherapy, significantly improves survival in cervical cancer, with benefits persisting even beyond an 8-week treatment window (5). Despite this, utilization in Korea declined from 84% in 2005 to 78% in 2013, with disparities linked to age, disease stage, and socioeconomic factors (6). Prognosis is also influenced by tumor size, stage, and pathology (6). Despite its therapeutic benefits, radiotherapy for gynecologic cancers is often associated with gastrointestinal (GI), genitourinary (GU), and vaginal toxicities, with severe 3-year rates reported at 2.8%, 6.1%, and 3.6%, respectively (7).

Recent advancements in machine learning and predictive modeling offer promising avenues to enhance clinical decision-making in gynecologic oncology. By integrating patient-specific data, these technologies aim to predict the risk of severe toxicities, allowing clinicians to personalize treatment plans proactively and improve overall outcomes and quality of life (1, 8).

Artificial intelligence (AI) is increasingly recognized as a transformative tool in the diagnosis, treatment, and management of gynecologic cancers. The incorporation of AI-driven technologies into gynecologic oncology has the potential to improve diagnostic accuracy, optimize clinical decision-making, and enable tailored therapeutic approaches for affected patients (9).

AI applications have notably enhanced early detection capabilities, particularly through sophisticated image analysis and biomarker identification. For instance, AI-assisted ultrasound imaging has demonstrated improved preoperative diagnostic accuracy for ovarian masses, which is critical for guiding appropriate treatment strategies (10). Deep learning models, trained on extensive datasets, are capable of discerning subtle distinctions between normal and pathological tissues, achieving diagnostic performance comparable to expert clinicians (11).

Beyond diagnosis, AI facilitates refined risk stratification by analyzing clinical data and prior medical records, including human papillomavirus (HPV) status, to identify patients at elevated risk for cervical cancer. This stratification enables personalized screening and management protocols, optimizing care delivery and resource allocation (12, 13).

In cytopathology, AI-driven automation streamlines smear analysis, alleviating workload pressures on cytopathologists and enhancing screening throughput. Systems such as the Genius Digital Diagnostics System exemplify how AI can expedite cell analysis by digitally acquiring slides, segmenting features, and classifying images into categories warranting specialist review, thus improving workflow efficiency in cervical cancer screening programs (14, 15).

Given the rapid evolution and expanding integration of artificial intelligence in gynecologic oncology, this review aims to comprehensively summarize the current applications and advancements of AI technologies in the diagnosis, treatment, and management of gynecologic cancers. By critically examining recent developments, clinical impacts, and ongoing challenges, this paper seeks to provide insights into how AI can enhance patient outcomes and guide future research directions in this important field.

2. AI-ENHANCED ACCESS TO INFORMATION AND PERSONALIZED EDUCATION

2.1. AI-Powered Chatbots for Cancer Patient Support

Recent advancements in artificial intelligence have significantly improved patient access to timely, accurate, and empathetic information. Notably, AI-driven chatbots—such as “Dave” by Belong.Life—are increasingly deployed to support cancer patients by delivering context-aware, emotionally intelligent, and clinically reliable responses. These systems are trained on oncology-specific datasets, enriched with large-scale patient interaction data and refined through sentiment analysis algorithms to improve contextual sensitivity and emotional engagement (16).

Empirical studies have demonstrated the clinical utility of such tools, indicating that AI chatbots may outperform physicians in perceived empathy and communication clarity. This improved interaction quality has been associated with a notable 30–40% reduction in unnecessary clinical visits, as patients are able to resolve routine concerns through virtual engagement (17, 18). Underlying these chatbots are natural language processing (NLP) models that are continuously optimized to enhance personalization, responsiveness, and patient engagement (17).

In addition to conversational support, advanced AI systems are capable of generating personalized health reports by synthesizing data from biomarkers, genomic profiles, wearable sensors, and patient-reported outcomes. These reports play a crucial role in translating complex clinical information into patient-friendly formats, thereby facilitating shared decision-making and improving the quality of discussions between patients and healthcare providers (19).

2.2. Personalized AI-Driven Cancer Education

AI is also revolutionizing cancer education by delivering personalized, adaptive learning experiences tailored to patients' clinical profiles and learning needs (20). Leveraging reinforcement learning and NLP technologies, AI-based educational platforms provide individualized content, including treatment-specific guidance aligned with clinical standards, evidence-based strategies for side-effect management, and self-care instructions informed by behavioral and biometric data (21).
These platforms are further augmented by virtual health assistants that dynamically adjust educational content based on patient feedback and treatment progress (22). The integration of multimodal delivery formats—such as interactive videos, voice support, and chat-based interfaces—enhances user engagement and accessibility. Continuous machine learning refinement ensures that the educational modules evolve in tandem with user needs, treatment changes, and emerging clinical evidence (22).

2.3. AI-Powered Decision Aids for Treatment Selection

Artificial intelligence is increasingly embedded in clinical decision support systems (CDSS), enhancing the decision-making process for both clinicians and patients. These AI-powered tools provide personalized treatment recommendations, risk-benefit analyses, and outcome forecasts based on integrated data sources, including clinical guidelines, individual medical histories, and genomic information (23). Supervised machine learning algorithms are employed to align patients with optimal therapeutic options, while predictive models estimate treatment responses using molecular and phenotypic features (23, 24).
To foster transparency and build trust among users, many systems incorporate explainable AI (XAI) frameworks that clarify the rationale behind algorithmic suggestions (25). Furthermore, AI-based predictive analytics contribute to comprehensive treatment planning by estimating survival probabilities from retrospective datasets, evaluating potential toxicity through pharmacogenomic analyses, and integrating quality-of-life considerations derived from both patient-reported outcomes and clinical trial data (25).

3. AI-SUPPORTED SELF-MANAGEMENT AND REMOTE MONITORING

3.1. Digital Twins for Personalized Health Simulations

The integration of artificial intelligence into digital twin technologies is redefining personalized cancer care by enabling the creation of dynamic, data-driven virtual patient models. These digital twins simulate individual disease trajectories, anticipated treatment responses, and potential complications, thereby providing clinicians with actionable insights for optimizing therapeutic strategies (26).
Constructed using AI-based predictive modeling, deep learning algorithms, and real-time data assimilation, these virtual replicas incorporate a wide range of multimodal inputs. These include genomic and molecular profiles, clinical histories, therapeutic responses, patient-reported outcomes, and biometric data from wearable devices. This comprehensive data fusion enables the simulation of highly individualized health scenarios, facilitating proactive decision-making and reducing dependence on empirical or trial-and-error approaches (26).
Digital twin frameworks also support longitudinal patient monitoring and adaptive treatment planning by continuously updating predictions based on new data inputs, thus offering a robust platform for real-time personalization in oncology.

3.2. AI-Powered Symptom Tracking for Remote Patient Monitoring

AI-enabled symptom tracking tools are enhancing remote patient monitoring by utilizing wearable sensors and mobile health (mHealth) platforms to collect, analyze, and interpret patient-generated health data in real time. These systems apply machine learning and pattern recognition algorithms to monitor clinical parameters such as pain levels, fatigue, heart rate, and other vital signs, offering early detection of adverse events—including chemotherapy-induced cardiotoxicity (27).
Crucially, these AI algorithms can detect subtle changes in physiological or behavioral patterns, identifying signs of clinical deterioration up to 48 hours before conventional clinical assessments would typically flag concern. This early warning capability supports timely medical intervention, reduces hospital admissions, and improves patient outcomes (27).
To address privacy concerns inherent in real-time health surveillance, federated learning approaches have been employed to enhance predictive accuracy while preserving data security. These models allow decentralized AI training across multiple sources without transferring raw patient data, thereby maintaining confidentiality while enabling population-scale learning (28).

4. AI-ENHANCED DIAGNOSTIC AND TREATMENT PLANNING

4.1. AI in Imaging and Early Detection

Artificial intelligence has significantly advanced diagnostic imaging in oncology by enhancing tumor detection, segmentation, and classification across multiple modalities, including MRI, CT, ultrasound, and PET scans (29). These innovations contribute to earlier diagnosis, more precise treatment planning, and improved targeting in interventional procedures.

4.2. Tumor Detection and Segmentation

Deep learning models, especially convolutional neural networks (CNNs) such as UNet, DeepLabV3+, and Mask R-CNN, have demonstrated high accuracy in tumor segmentation tasks. For instance, UNet-based architectures applied to CT and cone-beam CT (CBCT) imaging of rectal cancer have achieved Dice similarity coefficients up to 85%, supporting their integration into radiation therapy planning workflows (30, 31). Likewise, ensemble learning models that combine PET and CT imaging modalities have surpassed conventional methods in identifying metabolically active tumor regions by leveraging large-scale annotated datasets to improve sensitivity and specificity (32).

In gynecologic oncology, AI-driven segmentation algorithms have improved the delineation of ovarian and endometrial tumors on MRI and transvaginal ultrasound, leading to reduced interobserver variability and enhanced efficiency in radiologic reporting (33). These advancements facilitate accurate radiation dosing, better surgical planning, and precise monitoring of treatment response.

4.3. Improving Diagnostic Accuracy with Radiomics and Multimodal Integration

Radiomics-based AI models further augment diagnostic precision by extracting quantitative features from imaging data to differentiate benign from malignant lesions (34). These features include texture patterns, shape descriptors, and spatial heterogeneity indices, which collectively offer superior classification compared to conventional visual assessment (33, 34).

Deep residual networks (ResNet) applied to ultrasound imaging have demonstrated notable improvements in differentiating borderline ovarian tumors, endometrial hyperplasia, and invasive cancers (35). Moreover, combining MRI with ultrasound elastography enhances lesion characterization and improves the accuracy of image-guided biopsies by optimizing needle placement and spatial resolution (34).

5. METABOLOMICS AND BIOMARKER ANALYSIS

5.1. AI-Driven Metabolomic Profiling

Artificial intelligence also plays a pivotal role in metabolomics, where graph neural networks (GNNs) and autoencoders are used to analyze high-dimensional biochemical data. These models enable the identification of metabolic signatures that correlate with tumor progression, therapeutic resistance, and immune evasion—key factors in guiding precision oncology interventions (36).

6. AUTOMATED TREATMENT PATHWAY OPTIMIZATION

6.1. AI-Guided Therapy Recommendations

AI-powered clinical decision-support systems (CDSS) are now being integrated into oncology care to optimize treatment selection. These systems synthesize data from genomic sequencing, histopathologic assessments, and clinical records to generate personalized therapeutic recommendations. Models trained on datasets such as The Cancer Genome Atlas (TCGA) and real-world electronic health records (EHRs) have achieved high predictive accuracy in tailoring chemotherapy regimens, targeted therapies, and immunotherapies, particularly for gynecologic malignancies (37).

6.2. Predictive Analytics for Treatment Response

Emerging AI models such as MAMILNet have demonstrated robust capabilities in forecasting treatment outcomes in high-grade serous ovarian carcinoma. By analyzing histopathologic and genomic features, these models predict chemotherapy resistance with high precision, enabling oncologists to anticipate suboptimal responses and adjust therapeutic strategies proactively (38). Such predictive tools support more effective treatment planning and can improve both survival outcomes and patient quality of life.

7. AI-DRIVEN EMOTIONAL AND PSYCHOLOGICAL SUPPORT

7.1. AI-Enhanced Mental Health Monitoring

AI-enabled mental health monitoring represents a transformative advancement in supportive oncology care, enabling early detection of psychological distress and the delivery of individualized therapeutic strategies. These technologies integrate NLP, sentiment analysis, and biosensor-derived data to support mood tracking, cognitive behavioral therapy (CBT) delivery, and clinical decision-making in real time (39).

Recent progress in NLP using deep learning models such as BERT, GPT, and RoBERTa has enhanced the detection of anxiety and depression in cancer care settings. A study at the University of British Columbia demonstrated that NLP-based models analyzing oncology consultation transcripts could identify linguistic markers of psychological distress, achieving over 70% accuracy in predicting the need for psychiatric intervention within a 12-month period (40). Similarly, sentiment analysis approaches utilizing prosodic cues, lexical stress patterns, and semantic markers have proven effective in flagging early signs of emotional distress (41, 42).

Emotion recognition algorithms, trained on multimodal data such as voice recordings and textual inputs, have also been successfully deployed in gynecologic oncology settings to assess patient distress levels and facilitate targeted mental health interventions (43). Beyond detection, AI-powered tools deliver continuous emotional monitoring and therapeutic feedback. For example, speech-based systems can detect fluctuations in vocal biomarkers and offer adaptive, real-time CBT-based interventions (42, 44).

Mobile health (mHealth) platforms incorporating AI chatbots have shown promise in delivering personalized mental health support to adolescents and young adults with gynecologic cancers. These tools facilitate engagement through self-help CBT exercises tailored to individual coping styles and emotional needs, thereby promoting resilience and psychological well-being (44). In parallel, AI-integrated wearable devices monitor physiological markers such as heart rate variability, sleep disturbances, and activity levels, providing correlates of mental health status and enabling timely clinical response to stress-related deterioration (45).

Together, these AI-driven approaches contribute to a proactive model of psycho-oncology care by supporting early identification of psychological distress, tailoring interventions, and integrating emotional health monitoring into routine cancer management workflows (39).

7.2. AI-Facilitated Virtual Support Groups

AI is also enhancing the structure and effectiveness of online support communities for cancer patients by improving user matching, moderating discussions, and augmenting therapist-led interventions. These tools help mitigate social isolation, provide timely emotional support, and foster community engagement.

Patient matching algorithms, based on collaborative filtering and clustering methods, facilitate personalized peer interactions by aligning users according to cancer type, treatment phase, age, cultural background, and psychosocial profiles (46, 47). For example, matching individuals with recurrent ovarian cancer to peers undergoing similar experiences enables more meaningful exchanges and sustained engagement in virtual support groups.

In therapist-led virtual environments, AI-powered moderation tools assist clinicians by detecting real-time emotional cues such as sadness, fear, and suicidal ideation. A Canadian research initiative in Ontario developed an AI-enhanced moderation system capable of identifying distress markers within online discussions and flagging participants for immediate follow-up (48). These systems also utilize topic modeling and sentiment analysis to dynamically adapt group discussions, prioritize high-risk individuals, and ensure therapeutic responsiveness within the digital space (48).

7.3. Conversational AI for Emotional Support

Conversational AI tools are increasingly employed to deliver psychological first aid, stress management techniques, and mindfulness interventions. These systems offer scalable mental health support and reduce the burden on overstretched human resources in oncology care.

Advanced chatbots—powered by models such as GPT-4, Woebot, and Wysa—provide real-time emotional support through evidence-based strategies, including cognitive restructuring, guided relaxation, and automated triaging to crisis intervention services when severe distress is detected (49, 50). Clinical studies indicate that these tools can significantly reduce anxiety and depressive symptoms during chemotherapy, survivorship, and post-treatment recovery.

AI-enhanced mindfulness platforms use adaptive algorithms to personalize stress reduction interventions based on user behavior and engagement. These platforms incorporate guided meditation that adjusts to stress levels, biofeedback-driven relaxation using physiological markers (e.g., respiratory rate and heart rate variability), and AI-curated sleep therapy protocols combining CBT for insomnia (CBT-I) with individualized sleep hygiene recommendations (51-53). Collectively, these applications improve patients' psychological resilience, emotional regulation, and overall quality of life.

8. AI IN SURVIVORSHIP CARE AND LONG-TERM MONITORING

8.1. AI-Enabled Survivorship Care Plan (SCP) Generation

The integration of artificial intelligence into survivorship care planning is transforming follow-up care for cancer patients by enabling the generation of dynamic, personalized Survivorship Care Plans (SCPs) (54). These AI-enabled SCP systems draw from diverse data sources—including electronic health records (EHRs), patient-reported outcome measures (PROMs), and wearable sensor data—to deliver real-time, evidence-based updates that support long-term care engagement and patient empowerment (54).

AI-powered clinical decision support systems (CDSS), exemplified by platforms such as SurvivorPlan and the PERSIST H2020 project, utilize rule-based algorithms and machine learning models to synthesize oncology-specific data into comprehensive treatment summaries (55) (56). These systems also provide individualized lifestyle and health behavior recommendations by leveraging predictive analytics (57), while dynamically adjusting follow-up schedules in response to emerging clinical information (58). The PERSIST H2020 initiative, in particular, demonstrates a scalable AI framework that integrates big data analytics, wearable device feedback, and PROMs to enhance continuity of care during survivorship (55). This AI-driven approach addresses challenges related to fragmented data and fosters patient-centered care by offering actionable, real-time insights throughout the post-treatment period.

8.2. AI-Powered Recurrence Prediction Models

AI has revolutionized cancer surveillance by enabling the development of high-performance recurrence prediction models. These systems employ deep learning architectures, such as convolutional neural networks (CNNs), support vector machines (SVMs), and hybrid AI frameworks, to analyze multimodal datasets—including genomic profiles, histopathology images, radiomic features, and longitudinal EHR data—for the early identification of recurrence risk (59) (60) (61).

In gynecologic oncology, AI-based recurrence models have demonstrated superior predictive accuracy compared to traditional methods. For instance, AI frameworks that integrate molecular profiling and immune phenotyping have improved recurrence risk stratification in endometrial cancer, outperforming conventional prognostic tools (62). In ovarian cancer, AI-enhanced liquid biopsy analysis of circulating tumor DNA (ctDNA) enables early relapse detection, often preceding clinical symptom onset (63). Similarly, machine learning models incorporating radiomics and HPV genomic data in cervical cancer have shown utility in recurrence risk stratification, aiding in the development of tailored surveillance strategies (64). These advancements offer oncologists enhanced capabilities to monitor disease progression and intervene at the earliest possible stage, ultimately improving survival outcomes.

8.3. AI-Integrated Wearable Biosensors for Continuous Monitoring

Wearable biosensors, increasingly integrated with AI-driven analytics, are reshaping survivorship monitoring by enabling the continuous, non-invasive collection of physiological and behavioral data. Devices such as smartwatches and biosensor patches capture metrics including heart rate variability (HRV) and circadian rhythm patterns, which are correlated with immune function, stress levels, and recurrence risk (65).

In endometrial cancer, for example, AI-analyzed data from continuous glucose monitoring (CGM) and metabolic markers offer additional insights, especially in patients with coexisting metabolic syndrome (66). Moreover, tracking inflammatory biomarkers such as C-reactive protein (CRP) and interleukin-6 (IL-6) can provide early warning signs of systemic inflammation or disease progression (67).

By applying AI to these continuous data streams, clinicians can personalize post-treatment monitoring, reduce unnecessary clinical visits, and detect early signs of recurrence or comorbidity. This real-time feedback loop facilitates proactive intervention, potentially improving both clinical outcomes and patient quality of life.

8.4. Digital Twin-Based Follow-Up Strategies

The application of digital twin technology—virtual patient replicas created through the integration of clinical, genomic, and behavioral data—represents a novel frontier in survivorship care. These AI-driven simulations predict individualized post-treatment trajectories, including recurrence risk, long-term treatment-related toxicity, and the effects of behavioral interventions (e.g., exercise, diet, medication adjustments) (68).

In gynecologic oncology, digital twins have shown potential in tailoring post-treatment strategies. For instance, in endometrial cancer, models integrating tumor microenvironment characteristics and immunotherapy response data offer refined recurrence predictions (69). In ovarian cancer, digital twins developed using multi-omics data (genomics, transcriptomics, proteomics) allow for personalized forecasts of secondary malignancies and treatment-related complications (70). Similarly, in cervical cancer, digital twin systems that model HPV clearance dynamics and cytopathological risk factors enable precision surveillance planning for high-risk individuals (71).

These predictive simulations enable oncologists to implement personalized, data-driven follow-up strategies that anticipate complications and support long-term survivorship planning. As digital twin technology continues to evolve, it holds promise for becoming a cornerstone of proactive, precision survivorship care.

9. AI IN LIFESTYLE AND BEHAVIORAL HEALTH SUPPORT

9.1. AI-Personalized Diet and Nutrition Plans

Artificial intelligence is increasingly shaping nutritional support in oncology by enabling the development of personalized, data-driven dietary interventions. AI-powered nutrition platforms utilize machine learning algorithms and predictive modeling to analyze patient-specific factors—such as biometric data, treatment modalities, and symptom profiles—to generate tailored meal plans that align with oncology nutrition guidelines (72). These systems address common nutritional challenges in cancer care, including anorexia, treatment-induced nausea, and micronutrient deficiencies (73, 74). Evidence suggests that AI-guided nutritional interventions significantly enhance adherence to dietary recommendations, resulting in improved symptom control, energy levels, and overall patient well-being (75, 76). In addition, advanced food tracking tools leverage deep learning and computer vision to enable automated nutrient analysis from smartphone-captured images of meals, minimizing the limitations of manual dietary logs (77). This AI-assisted technology not only enhances the accuracy of nutritional monitoring but also plays a pivotal role in preventing malnutrition, which is associated with poor treatment tolerance and adverse clinical outcomes in oncology (78). Studies further indicate that AI-enabled food tracking systems contribute to better weight maintenance, immune function, and treatment continuity by supporting real-time dietary adjustments during cancer therapy (77, 78).

9.2. AI-Guided Exercise and Rehabilitation

AI-driven exercise and rehabilitation platforms are emerging as valuable tools in survivorship care, particularly in gynecologic oncology, where patients often experience fatigue, sarcopenia, and functional impairments following treatment. These systems generate individualized exercise programs by incorporating real-time physiological data from wearable sensors, patient-reported outcomes, and recovery metrics (79). Virtual coaching platforms adapt exercise prescriptions based on ongoing monitoring of fatigue, pain, mobility, and cardiovascular responses, ensuring alignment with evidence-based rehabilitation guidelines (80).

Empirical studies have demonstrated that AI-personalized exercise interventions improve physical activity levels, reduce cancer-related fatigue, and enhance cardiovascular and musculoskeletal health in cancer survivors (80). Furthermore, AI-powered motion analysis tools employing wearable inertial sensors and computer vision provide real-time feedback on posture and movement patterns (81). These systems are especially effective in guiding post-surgical rehabilitation for gynecologic cancer patients, offering support for pelvic floor training, gait stabilization, and flexibility restoration while reducing the risk of musculoskeletal injury (82).

9.3. AI-Supported Sleep and Fatigue Management

Sleep disturbances and cancer-related fatigue are prevalent and debilitating symptoms that compromise quality of life, psychological resilience, and treatment adherence in cancer survivors. AI-enabled tools are being leveraged to address these challenges through continuous monitoring and personalized interventions.

AI-based sleep trackers integrate data from wearable devices and smartphone sensors to analyze sleep architecture, circadian rhythm disruptions, and nocturnal awakenings (83, 84). These platforms generate individualized recommendations that combine CBT-I, mindfulness techniques, and environmental modifications to enhance sleep hygiene (84). Notably, platforms such as Nurse AMIE have demonstrated efficacy in improving sleep quality among metastatic breast cancer patients via AI-guided relaxation protocols (85).

In parallel, AI-driven fatigue management systems apply the 3P model—Predisposing, Precipitating, and Perpetuating factors—to build predictive models of cancer-related fatigue (86, 87). These models synthesize biological data (e.g., inflammatory markers), psychological profiles, and lifestyle factors (e.g., physical activity, sleep patterns) to tailor behavioral interventions, such as nutritional optimization, structured exercise, and circadian rhythm regulation (87). Studies highlight that these AI-based interventions reduce fatigue severity, promote functional independence, and improve adherence to cancer therapies in gynecologic oncology populations.

10. LIMITATIONS OF AI APPLICATIONS IN GYNECOLOGIC CANCER CARE

Despite the transformative potential of AI in gynecologic cancer care, several limitations hinder its optimal implementation. Data bias and representation remain critical challenges, particularly when training AI models on datasets that inadequately represent minority populations, older adults, or patients in rural or low-resource settings. This underrepresentation compromises the accuracy of personalized education, treatment recommendations, and lifestyle guidance, risking disparities in care. Moreover, the heterogeneity and quality of diagnostic and clinical data further limit the generalizability of AI models across diverse clinical settings. Ensuring external validation and data standardization is crucial to mitigate this issue. Additionally, the "black box" nature of many AI algorithms can undermine trust, as clinicians may find it difficult to interpret or validate the decisions made by these models.

In the realm of self-management and remote monitoring, AI-driven solutions face barriers related to patient engagement, compliance, and digital literacy. Many patients may struggle to consistently use AI-enhanced tools due to limited access to technology, low digital literacy, or psychological and emotional challenges. Compounding this issue, AI systems often provide limited personalized feedback and lack the empathetic responses offered by human providers, which are essential for addressing the emotional and psychological needs of patients undergoing cancer treatment. Additionally, privacy and security concerns regarding the handling of sensitive health data pose ethical and regulatory challenges that must be addressed to ensure patient safety and trust.

In terms of survivorship care and long-term monitoring, the scarcity of robust longitudinal data restricts the development of AI models capable of accurately predicting quality of life and long-term health outcomes. Furthermore, integration challenges with existing healthcare systems can disrupt care continuity and delay the adoption of AI-driven interventions. There is also a risk of over-reliance on AI recommendations, which may lead healthcare providers to overlook critical clinical nuances and individualized patient needs.

For behavioral health and lifestyle support, AI algorithms often struggle to navigate the complexities of individual behavior, social contexts, and cultural factors. Without sufficient personalization, these tools may unintentionally reinforce unhealthy behaviors or promote unrealistic expectations, especially among underrepresented populations. Lastly, ethical concerns surrounding deception and trust arise when patients are unaware that they are interacting with AI systems, which may erode confidence in digital health tools. Addressing these multifaceted limitations will require ongoing interdisciplinary research, regulatory oversight, and collaborative innovation to ensure that AI technologies in gynecologic cancer care are equitable, transparent, and patient-centered.

11. FUTURE DIRECTIONS OF AI APPLICATIONS IN GYNECOLOGIC CANCER CARE

To address existing limitations and maximize the potential of AI in gynecologic cancer care, future advancements should focus on enhancing inclusivity, personalization, and transparency across multiple dimensions. Data diversification and bias mitigation are paramount; actively curating heterogeneous datasets representing various demographics—including race, socioeconomic status, and geographic regions—will ensure more equitable AI-driven information delivery and personalized education. Moreover, developing AI-powered fact-checking systems to validate the accuracy and currency of educational content can mitigate misinformation and reduce patient anxiety. Integration with telemedicine and mobile health (mHealth) platforms will facilitate more accessible consultations and follow-ups for patients in remote or underserved areas (88).

For self-management and remote monitoring, ensuring data privacy remains essential. Techniques such as federated learning and differential privacy can facilitate secure data sharing without compromising confidentiality. To improve patient engagement and adherence, incorporating gamification and behavioral nudges into AI platforms can make remote monitoring more interactive and rewarding. Developing AI-driven virtual assistants with emotional intelligence that can detect subtle emotional cues and provide empathetic responses will further enhance patient support, especially in moments of psychological distress.

In diagnostic and treatment planning, standardizing protocols for data collection, annotation, and quality control is crucial for improving data consistency and model performance. Employing federated and transfer learning techniques will help generalize AI models to diverse populations, while XAI frameworks can improve transparency by providing clinicians with clear insights into AI-driven recommendations. This will foster trust and collaboration in clinical decision-making.

For emotional and psychological support, context-aware dialogue systems that utilize NLP to recognize and adapt to patients' emotional states can offer tailored support. Establishing ethical frameworks to ensure transparency and patient autonomy, including disclosure of AI use and the option for human interaction, will be vital for building trust. In survivorship care and long-term monitoring, creating comprehensive longitudinal data registries that capture patient outcomes, quality of life, and long-term side effects will strengthen predictive models for recurrence and complications. Seamlessly integrating these models with lifestyle and behavioral health interventions can promote holistic care, encouraging healthy habits and improving overall well-being. Lastly, leveraging hybrid AI models that combine machine learning with clinical expertise will enhance the effectiveness of behavioral health interventions, providing culturally and contextually tailored recommendations.

By pursuing these directions, AI in gynecologic cancer care can evolve into a more equitable, effective, and patient-centered tool, improving both clinical outcomes and the quality of life for affected individuals.

12. CONCLUSION

Artificial intelligence is rapidly transforming gynecologic oncology by enhancing diagnostic accuracy, enabling personalized risk assessment, and improving clinical workflows. While current AI applications demonstrate significant potential in optimizing treatment outcomes and reducing toxicity, challenges such as data standardization, algorithm validation, and integration into diverse clinical settings must be addressed. Continued multidisciplinary collaboration and rigorous research are essential to fully realize AI's benefits and ensure its safe, equitable adoption in gynecologic cancer care.

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Conflict of interest

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Ethical statement

This research did not involve ethical considerations.

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