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Innovative and future approaches for ovarian cancer detection and evaluation: a comprehensive review

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Abstract

Gynecological malignancies, characterized by their aggressive nature and tendency to recur, are associated with poorer outcomes and suboptimal responses to available treatment modalities. Ovarian cancer (OC) is frequently present at advanced stages, wherein therapeutic resistance, angiogenesis, recurrence, and metastatic spread significantly affect patient survival rates. The primary therapeutic approaches for this condition include surgical debulking, radiotherapy, and/or chemotherapy. Nevertheless, in the absence of targeted interventions, patients frequently experience undesirable side effects and develop resistance to pharmaceutical agents. Therefore, it is critical to understand the intricate physiology of diseases and to identify biomarkers that may help with early diagnosis or therapy response prediction. This comprehensive review seeks to critically analyze modern-day therapeutic approaches for OC, investigate innovative drug delivery mechanisms, and assess prospective biomarkers through the lens of genetic and molecular scientific inquiry. It emphasizes how technological advancements enhance disease biological processes, facilitating the identification of novel biomarkers that may refine diagnosis and prognosis, resulting in tailored medicines that improve patient survival and quality of life.

Key words ovarian cancer, CA125, biomarkers, pathways, autophagy

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Introduction

The word "ovarian cancer" (OC) refers to a diverse array of carcinomas that develop in ovarian tissue, characterized by discrete clinicopathological and genomic characteristics, as well as distinctive tissue sources [1]. Anomalous proliferation of atypical cells characterizes the initiation of a potential malignancy within the ovary. These cells subsequently undergo unrestricted replication, which may lead to infiltration of adjacent organs, thus establishing malignant neoplastic growth [2, 3]. The ovarian tissue comprises three cellular classifications, each possessing the potential to generate diverse tumour varieties [4]. Most ovarian neoplasms originate from the epithelial tissue, encompassing high-grade and low-grade serous carcinomas and clear cell, endometrioid, and mucinous variants. In contrast, stromal-type ovarian cancers account for approximately 7% of all cases, while germ cell tumor-derived OCs are infrequently encountered [5]. Studies have revealed that OC often exhibits precursory indicators; however, the initial symptoms tend to be elusive and challenging to identify as they coincide with prevalent gastrointestinal, genitourinary, and gynecological disorders [6]. Several obstacles prevent this condition from being treated effectively [7, 8]. Although initial chemotherapy and radical surgery yield high response rates for approximately 70% of patients experiencing relapse, with intermediate progression-free survival spanning 12–18 months, the mechanisms underlying long-term survival remain poorly elucidated, accompanied by a significant risk of disease recurrence [9].

In 2022, epidemiological projections from the American Cancer Society indicated that 19,800 individuals in the United States will receive a new diagnosis of OC, while the disease is anticipated to claim the lives of 12,810 women [10]. The elevated mortality associated with high-grade serous carcinoma (HGSC) is predominantly attributable to challenges in disease detection, particularly during the early stages when clinical interventions demonstrate optimal efficacy [11]. Furthermore, chemotherapeutic interventions for OC substantially compromise patients' quality of life owing to severe adverse reactions, including fatigue, arthralgia, and neurotoxicity [12, 13]. Hence, advances in more precise and efficacious techniques for detecting OC in its incipient stages could yield substantial improvements in patient prognosis.

Pharmaceutical delivery and co-delivery mechanisms within ovarian carcinoma management represent critical avenues for therapeutic interventions. Drug delivery systems have been engineered to incorporate either single-target compounds or multiple-target agents, thereby enhancing the efficiency of drug release and mitigating the associated toxicity. This study aimed to assess the current understanding of OC encompassing its related signalling pathways, targeted treatment approaches, and innovative drug delivery methodologies.

Risk factors

The etiology of OC encompasses a multifaceted display of risk factors that can be broadly classified into genetic and non-genetic categories. These non-genetic elements comprise various aspects, including an individual's reproductive history, the utilization of exogenous hormones, pre-existing medical conditions, lifestyle choices, and environmental influences. Each of these factors contributes to the overall risk profile of OC development [14]. Substantial evidence indicates that the primary risk factors for this pathology include a familial history of OC, mainly when a relative receives a diagnosis before 50 years of age, and germline BRCA1/BRCA2 mutations [15, 16] (**Figure 1**). Genetic alterations in MSH2, MSH6, MLH1, PMS2, and EPCAM, which are associated with Lynch syndrome, as well as mutations in BRIP1, PALB2, RAD51C, and RAD51D, have been implicated in increased susceptibility to OC. Research suggests that inherited genetic mutations are responsible for approximately 18% of epithelial malignancies, except high-grade serous carcinomas [17, 18].

Epidemiology

OC represents a substantial health challenge, ranking as the eighth most prevalent malignancy affecting women globally [19]. Geographical disparities in incidence rates are evident, with developed nations such as North America and Europe demonstrating higher prevalence, whereas Asian and African countries exhibit comparatively lower frequencies [20, 21]. Globally, this condition has resulted in an estimated 313,959 new diagnoses and 207,252 fatalities in 2020. The condition predominantly afflicts females in their postmenopausal years, with the highest occurrence observed in the 50-70 age bracket [22, 23]. Despite significant progress in therapeutic modalities, the overall prognosis remains unfavorable as most cases are detected at advanced stages, thus contributing to the high mortality rates associated with this condition.

OC screening

Transvaginal ultrasound

Ultrasound screening technology facilitates the in-depth examination of ovarian structures, enabling the identification of potential morphological alterations that may indicate the emergence of malignant neoplasms [24]. Transvaginal ultrasonography (TVU) is the predominant imaging method used for the detection of OC. This enables healthcare practitioners to discern anomalies in ovarian tissue morphology and dimension. Using TVU, radiologists conduct assessments of specific clinical attributes according to the International Ovarian Tumor Analysis (IOTA) criteria. The evaluation process involved scrutinizing various features, including papillary projections, ascites, and patterns of internal blood flow. These observations serve as crucial indicators for estimating the probability and extent of malignant masses [25].

CA125

CA125, a glycoprotein expressed on the surface of epithelial cells, is the predominant biomarker for OC and facilitates the proliferation and dissemination of malignant cells [26]. Preliminary studies on CA125 revealed that approximately 80% of individuals with OC exhibited elevated serum levels of this protein, exceeding 35 U/mL [27]. Unfortunately, further investigations into the clinical benefit of CA125 screening have yet to demonstrate substantial benefits to patients, primarily due to a lack of clinical sensitivity for CA125 at the early stages of the disease. The efficacy of CA125 levels in enhancing the differentiation of ovarian masses appears to be constrained when integrated into multifaceted diagnostic strategies during preoperative evaluation [28].

In 2016, a landmark study on OC screening was published by Jacobs et al., who presented the results of the United Kingdom Collaborative Trial of Ovarian Cancer Screening (UKCTOCS). This trial is one of the most extensive randomized controlled trials in OC research. This study examined the impact of early screening using the Risk of Ovarian Cancer Algorithm (ROCA) on OC mortality in over 200,000 post-menopausal women over an average of 11.1 years. To stratify patient risk, ROCA considers baseline and serially collected CA125 levels, patient age, menopausal status, and other risk variables, such as BRCA status.

Table 1. OC treatment with new biomarkers and its possible advancement.

Newly identified biomarkers	Origin	Prospective therapeutic function	Mechanism	References
Cu isotope ratio $\delta^{65}Cu$	Serum	The quantification of this substance in blood plasma or serum presents a potential avenue for non-invasive diagnostic or prognostic biomarker applications.	The upregulation of specific proteins, including ceruloplasmin, CTR1 (copper transporter 1), and ATP7A/ B , in cellular processes may exert an influence on the isotopic composition.	[30]
Extracellular Vesicles (EVs)	Blood, Ascitic fluid, urine etc.	EVs demonstrate potential as delivery vehicles for various therapeutic agents, including chemotherapeutic drugs, siRNAs, and CRISPR/Cas9 components, with specific application in targeting ovarian cancer cells.	Recipient cells undergo pro-tumorigenic pathway activation upon the transmission of oncogenic proteins, RNAs, and miRNAs.	[31]
Glutathione S-Transferase Polymorphisms (GSTP)	Blood or genetic materials (DNA etc.)	Genetic profiling of GSTP1 may help find women who are at a higher risk of OC, which might lead to more targeted screening programs and better ways to avoid the disease.	It aids in the elimination of electrophilic toxins by conjugating glutathione to them, hence decreasing their tendency to react.	[32]
Folate Receptor Alpha (FOLR1)	Blood/ Genes	It promotes folate absorption, which is essential for DNA formation, repair, and modification. In rapid-proliferating OC cells, increased FOLR1 expression increases folate bioavailability.	This molecule exhibits a high-affinity binding to folate, subsequently facilitating its cellular internalization through the process of endocytosis.	[33]
Aldehyde Dehydrogenase 1 (ALDH1)	Blood/ Cytosol of cells	In OC, heightened ALDH1 expression exhibits a significant correlation with more advanced stages of the disease, tumors of higher grade, and diminished OS and PFS durations.	ALDH1, an enzymatic catalyst, converts highly reactive aldehydes into less hazardous carboxylic acids. This metabolic pathway reduces oxidative stress-induced cell destruction.	[34]

Although the study revealed better survival in the screened groups, the results were insignificant, emphasizing CA125's limitations [29]. Although CA125 exhibits suboptimal efficacy as a screening biomarker, it yields substantial clinical advantages when used as a postoperative parameter. This marker is particularly valuable for assessing therapeutic responses and facilitating the detection of disease recurrence in patients. **Table 1** describes the therapeutic value of newly discovered biomarkers in treating OC and their possible future development.

Outlining multiple signaling pathways in OC

Within the therapeutic landscape of OC, surgical interventions and concurrent chemoradiotherapy are the predominant treatment strategies [35]. Nevertheless, chemoradiotherapy has been associated with considerable adverse effects, and the limited therapeutic efficacy of radiotherapy ultimately results in disease progression and suboptimal survival outcomes [36]. Therefore, selective modulation of specific signalling pathways has emerged as a promising molecular approach for OC therapeutics, potentially inhibiting neoplastic growth, cellular invasiveness, migratory capacity, and metastatic dissemination [37]. This section provides a concise overview of specific signalling pathways associated with tumorigenesis and metastasis that may be amenable to therapeutic interventions. Furthermore, this study elucidates the emerging inhibitors currently undergoing clinical evaluation.

PI3K/AKT/mTOR route

The PI3K/AKT/mTOR signalling axis represents the pivotal intracellular routes orchestrating cellular functions, encompassing growth, proliferation, differentiation, and survival [38, 39]. A multifaceted array of molecular mediators modulates this signalling cascade. These include various growth-promoting factors, notably IGF, EGF, and TGF. Additionally, the pathway is influenced by specific receptor tyrosine kinases, including IGF-1R, PDGFR, FGFR, HER2, and EGFR [40]. Furthermore, several associated receptor layers regulate this pathway [41, 42]. Evidence suggests a robust correlation between the anomalous expression and activation of AKT (pAKT) and diminished progression-free and overall survival outcomes in patients with epithelial OC [43, 44]. In high-grade serous OC, gene disruption frequently impairs the tumor-suppressing functions of RB1, PTEN, NF1, and RAD51B, as revealed by whole-genome sequencing. This genetic inactivation results in resistance to chemotherapy [45, 46]. The PI3K/PTEN/AKT signaling cascade is pivotal in directly modulating OC stemness, a critical regulatory element in aggressive malignancies. This modulation manifests in multiple ways, including augmentation of CSC populations, preservation of CSC phenotypic characteristics, and the emergence of multidrug resistance (MDR) mechanisms [47].

Experimental in vitro and in vivo studies have revealed the antineoplastic properties of SPR965, a compound that simultaneously targets the PI3K and mTORC1/2 signaling pathways. This dual inhibitor is effective against various solid malignancies, including serous ovarian neoplasms [48]. Nevertheless, additional clinical investigations are essential to validate its potential as a novel targeted therapeutic intervention before it can be recommended for clinical use. Further research has elucidated the role of ANGPTL3 in enhancing PTX sensitivity in

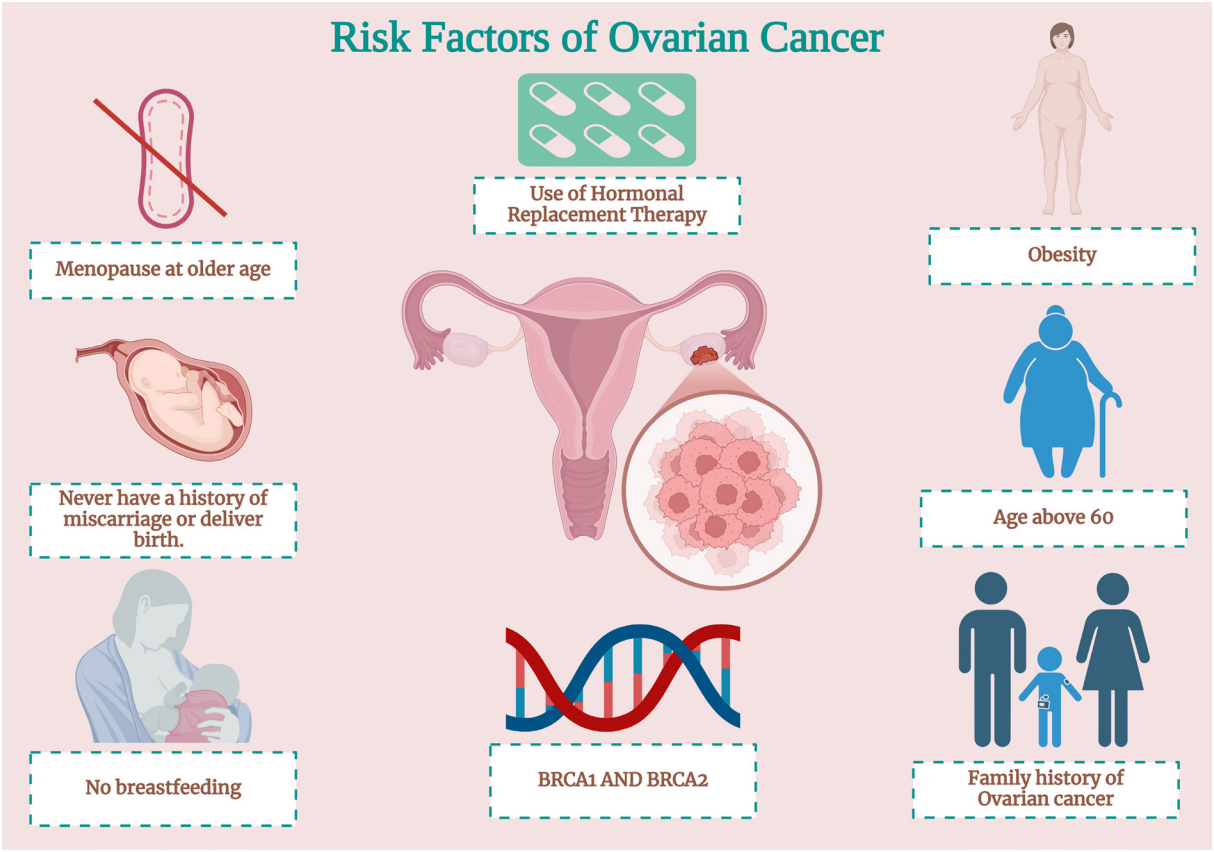

Figure 1. The risk factors of OC encompass a multifaceted spectrum of components, which can be systematically categorized into genetic, hormonal, reproductive, and lifestyle-associated elements.

OC by downregulating the PI3K-AKT-mTOR signaling pathway. The results of this investigation suggest that ANGPTL3 may emerge as a promising therapeutic target for OC, underscoring its potential significance in clinical strategies for managing this malignancy [49].

Apoptotic signaling pathway

Apoptosis, a meticulously regulated process of cellular self-destruction, is fundamental to maintaining equilibrium in multicellular organisms. This energy-dependent biochemical mechanism ensures a delicate balance between cell proliferation and elimination, thereby preserving overall tissue homeostasis [50, 51]. Regulation of mitochondrial membrane permeabilization, a critical process in the intrinsic apoptotic pathway, is orchestrated by two principal components: the B-cell lymphoma-2 (BCL-2) family and inhibitors of apoptotic proteins (IAPs). These molecular entities exert their influence by modulating caspase activation, thereby facilitating apoptotic switching [52]. In contrast, the extrinsic apoptotic pathway initiates a cell surface receptor signaling cascade via the tumor necrosis factor (TNF)-related apoptosis-inducing ligand (TRAIL) [53]. The activation of the caspase-3 pathway plays a pivotal role in the initiation of apoptosis. This phenomenon is demonstrated by the enhanced sensitivity to paclitaxel exhibited by human OC SKOV3.ip1 cells overexpressing HER-2/neu when exposed to adenoviral type 5 E1A [54]. Caspase-3 is a crucial enzyme that facilitates proteolytic degradation of cellular proteins and consequently advances the apoptotic cascade.

The polyphenolic compound resveratrol demonstrates the ability to enhance apoptotic processes via an AMPK-dependent pathway. Furthermore, this molecule facilitates caspase 3 activation, consequently leading to the downregulation of mTOR expression and activity [55]. In OC cells, mTOR is a downstream component of the AMPK signaling cascade. Enzastaurin functions as an ATP-competitive protein kinase C beta (PKC-beta) inhibitor and exhibits radiosensitizing properties, thus offering an alternative therapeutic approach. This compound suppresses tumor cell proliferation by amplifying the pro-apoptotic activities of caspase-3 and caspase-9 [56]. In human OVCAR-3 and OVCAR-4 cell lines, metformin's apoptotic effects are associated with several molecular changes. These include the reduction of Bcl-2 and Bcl-xL protein expression, the stimulation of caspase 3/7 activity, and the increase in Bax and Bad levels. Together, these alterations contribute to metformin's ability to trigger programmed cell death in these OC cells. Despite OVCAR-4 cells expressing Bcl-2, cisplatin increased metformin-induced apoptosis in OVCAR-3 cells without altering Bcl-2 levels [57].

The signaling pathway of JAK/STAT

Abnormal activation of the essential JAK/STAT signaling pathway is observed in OC. This ongoing stimulation significantly correlates with cancer development and unfavorable outcomes in individuals with these conditions [58]. In recent years, JAK inhibitors have become integral to cancer treatment. Clinical studies have demonstrated the effectiveness of various JAK inhibitors, and researchers are currently investigating additional inhibitors and related analogs for potential therapeutic applications. Preclinical investigations revealed that ruxolitinib,

an FDA-approved JAK inhibitor for polycythemia vera treatment, effectively diminished OC cell viability [59]. In a murine model, the JAK inhibitor AZD1480, a small-molecule compound, demonstrated efficacy in suppressing OC growth [60]. This inhibition was mediated through cascading effects, including attenuation of STAT3 phosphorylation, disruption of DNA binding processes, and impediment of migration and adhesion in cultured OC cells [61].

Elevated aldehyde dehydrogenase (ALDH) activity, a hallmark of endometrial tumor stem cells, promotes the upregulation of interleukin-6 (IL-6) and its associated signal transducers, CD126 and GP130. In contrast, inhibition of the IL-6 receptor significantly suppresses the downstream IL-6/JAK1/STAT3 signaling pathway, ultimately reducing tumor cell proliferation [62]. In conclusion, many human cancers are associated with persistent activation of the JAK/STAT system, and the impact, if any, of JAK inhibitors on cancer progression is unclear. Therefore, the safety and efficacy of JAK inhibitors remain uncertain.

Regulation of autophagy in the treatment of OC

Autophagy, a sophisticated cellular mechanism, plays a crucial role in maintaining homeostasis by facilitating the degradation and recycling of deleterious, redundant, or compromised organelles within cells [63, 64]. Emerging evidence suggests a significant role of autophagy in OC, as demonstrated by the expression of specific autophagy-associated proteins. These proteins, including microtubule-associated protein light chain (LC-3), beclin-1, and p53, are integral components of the autophagic machinery implicated in this malignancy [65, 66]. Research has shown that OC exhibits decreased beclin-1 expression when compared to non-cancerous lesions, indicating the potential value of this protein as a predictive marker in OC [67]. Furthermore, studies have revealed that Bcl-2 expression inhibits autophagy through its association with beclin-1, whereas increased levels of p53 protein might influence autophagic processes in OC cells. Subsequent clinical research has corroborated the p53-mediated regulation of autophagy [68].

Autophagy has been identified as a potential therapeutic target in OC because it constitutively activates the PI3K/AKT/mTOR signaling pathway. This activation has been observed in approximately 70% of OC cases, highlighting the significance of autophagy in disease progression and treatment strategies [69]. Sirtuin 3 (Sirt3), a crucial member of the Sirtuin protein family, exhibits a fundamental role in preserving intracellular homeostasis and regulating autophagy in OC through intricate reciprocal interactions. Research has demonstrated that overexpression of Sirt3, induced by metformin, promotes mitochondrial impairment and programmed cell death in OC cells via AMPK activation [70].

OC treatment through targeted drug-delivery systems

Standard chemotherapy for OC has several limitations, including rapid drug clearance, inadequate biodistribution, and undesirable side effects. In response to these challenges, researchers have engineered drug delivery systems (DDSs) to encapsulate anticancer medications and target their release into tumor cells [71]. These advanced DDSs encompass a range of formulations, for instance, liposomes, drug combinations, microspheres, micelles, and tiny particles, each addressing specific aspects of

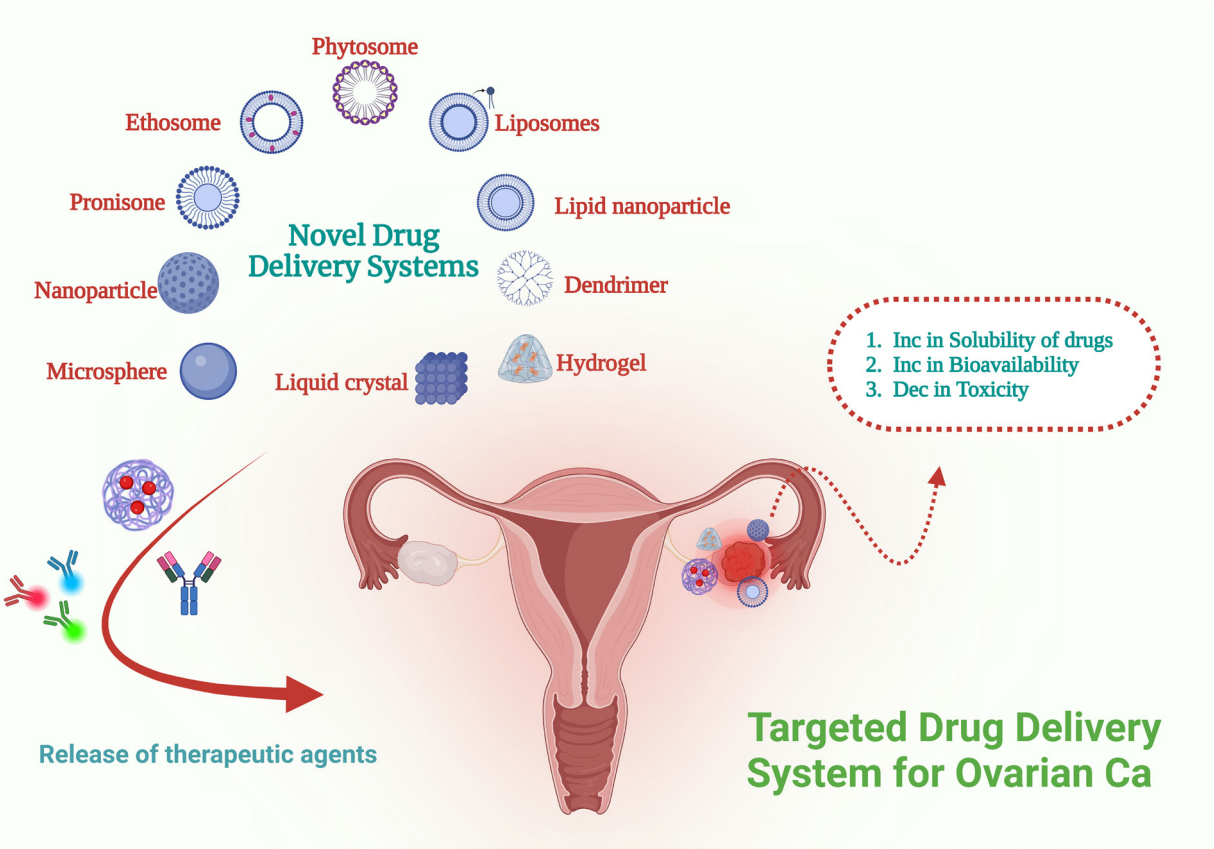

Figure 2. DDSs are specifically engineered to target ovarian neoplasms. These systems serve as vehicles for transporting therapeutic agents, which may include nucleic acids proteins, or various small molecules, to the affected tumor regions.

drug delivery optimization [72] (**Figure 2**). The field has witnessed substantial advancements in material properties and the refinement of continuous nanoparticle synthesis techniques. Concurrently, a notable surge of interest has emerged in exploring naturally occurring protein enclosures, particularly viral structures, as potential vehicles for drug delivery [73].

To augment the effectiveness of cancer therapies, researchers have integrated a minimum of one chemotherapeutic compound into nanoparticles via encapsulation or incorporation techniques. Cisplatin, a prevalent first-line treatment for ovarian malignancies, encounters dosage constraints owing to its nephrotoxic effects [74]. In response to these challenges, scientific investigations have focused on optimizing cisplatin distribution and alleviating renal toxicity through advanced surface modification and nanoparticle engineering techniques [75]. The chemotherapeutic agent doxorubicin (Dox) is widely employed in the treatment of OC and breast cancer therapy. However, its clinical application is limited by severe cardiotoxicity. To address this issue, researchers have explored the encapsulation of doxorubicin in DDS. In a novel approach, Zeng et al. utilized the cucumber mosaic virus (CMV) as a biological scaffold to synthesize nanoparticles capable of controlled doxorubicin release, potentially mitigating its toxic effects [76].

The development of nano drug co-delivery systems (NDCDSs) represents a significant advancement in cancer treatment, particularly in chemotherapy. These innovative systems are designed to address the limitations of single-drug therapies by incorporating a minimum of two antitumor agents with distinct biophysical and pharmacological characteristics [77]. The primary objective of NDCDSs is to enhance the therapeutic efficacy while mitigating the toxic effects of conventional monotherapy approaches [78]. Advancements in siRNA-based drug codelivery systems have yielded promising results. A novel dendrimer, synthesized using polypropylenimine (PPI), has demonstrated efficacy in simultaneously transporting paclitaxel and a siRNA specifically targeting CD44 mRNA [79]. This hypothesis posited that inhibiting the cell surface CD44 marker through siRNA-mediated mechanisms would impede metastatic progression and enhance the efficacy of chemotherapeutic regimens. Nevertheless, concerns regarding the safety of prolonged administration arise from various factors, including biodegradation, bioavailability, instability, tissue distribution, and potential toxicity, which pose significant challenges.

Advanced methods for treating OC

Improved prognosis in OC has been associated with discovering new therapeutic targets. The exploration of OC's complex biological mechanisms has led to significant breakthroughs in identifying a diverse array of molecular targets. These encompass crucial cellular components, such as growing factor receptors, cell cycle regulatory elements, transmission of signal, and angiogenic processes. This enhanced understanding has paved the way for novel therapeutic approaches in the field of oncology [80]. This section provides a comprehensive review of the primary therapeutic targets utilized in OC treatment, both as impartial interventions and in conjunction with cytotoxic agents. Additionally, it examines novel pharmaceutical compounds currently undergoing clinical trials.

The signaling pathway of angiogenesis and VEFG

Angiogenesis, the biological process through which new blood vessels are generated, facilitates the transport of essential nutrients and oxygen to adjacent tissues [81]. This mechanism consequently supports the growth, invasive capabilities, and metastatic spread of tumor cells [82]. Recent scientific investigations have illuminated the pivotal role of receptor tyrosine kinases (RTKs) in aberrant blood vessel formation, particularly within the context of tumor-associated angiogenesis. Notably, vascular endothelial growth factor (VEGF), its cognate receptor (VEGFR), and the Flk-1/KDR RTK have emerged as critical regulators in this pathological process [83].

Amongst VEGF-targeting therapeutic approaches for OC, bevacizumab, an antibody directed against VEGF, is the most thoroughly researched intervention [84, 85]. Recent clinical trials evaluating bevacizumab in OC treatment yield encouraging results, particularly in deuce pivotal initial phase investigations: ICON7 [86] and GOG 218 [87]. The GOG trial employs a three-drug regimen, comprising carboplatin/paclitaxel and bevacizumab, for the treatment of OC patients who have undergone minimal cytoreductive procedures [88].

Targets particular to OC: CA125 and MUC16

Following its initial identification over twenty years ago, the CA125 antigen has been approved for clinical use in OC screening among high-risk women in the United States. Subsequent studies identified it as a promising prognostic biomarker for preinvasive OC [89]. Lloyd et al. successfully identified and characterized the gene encoding the CA125 antigen, which they subsequently designated as MUC16 [90]. Rab-B3.13, a monoclonal antibody from mice, alternatively called OvaRex, exhibits a robust binding affinity towards the CA125 antigen. Consequently, antibodies derived from murine sources, specifically targeting CA125, have recently been investigated as possible treatment methods. The section I/II clinical study demonstrated that patients with persistent OC established immunological responses to oregovomab and CA125 when administered as a third-line therapeutic intervention. The observed immune reactions included the production of antibodies and T cells. Notably, anti-idiotype antibodies were detected in 66% of the study participants [91]. The administration of specific anti-idiotypic antibodies as a vaccination strategy may potentially augment survival rates among patients with recurrent OC, demonstrating a favorable side effect profile. As a result, combining non-invasive immunotherapy techniques with standard chemotherapy protocols could potentially improve survival rates in OC patients [92].

Compounds targeting tubulin

For breast cancer and various other malignancies, including those of the ovaries, prostate, head, neck, and lungs, microtubule-targeting agents like taxane and vinca alkaloids have been utilized as frontline therapies for an extended period. These compounds belong to a class of anticancer drugs that exert their effects by interfering with microtubule function [93]. Clinical trials in phase III revealed that CT2103, a polyglutamated variant of paclitaxel, exhibited enhanced therapeutic efficacy and reduced adverse effects compared to conventional paclitaxel. This cytotoxic compound demonstrated improved clinical outcomes whilst minimizing undesirable patient reactions [94]. The revised paclitaxel formulation boasts quicker administration and reduced hypersensitivity reactions. It demonstrates taxane-equivalent effectiveness in recurring OC, yielding a 23% response rate among patients with minimal prior treatment [95]. Nevertheless, the medication's oral form exhibits poor absorption characteristics.

Conclusion

OC constitutes a lethal gynecologic disorder that impacts female populations on a global scale. The absence of reliable diagnostic

biomarkers contributes to the late-stage detection of OC in a significant proportion of affected women, thereby diminishing their survival prospects. The development of chemotherapy resistance in advanced-stage OC poses a substantial clinical dilemma attributed to the complex interplay of multiple signaling pathways underlying the mechanisms of this resistance. Identifying molecular alterations in OC presents a significant challenge, yet it remains essential for selecting suitable therapeutic agents, given their potential to improve clinical outcomes. This complex and diverse disease necessitates a thorough grasp of its biological underpinnings to facilitate more targeted and precise investigations into its underlying mechanisms. The field of OC research has witnessed significant strides in understanding its underlying biology. This enhanced comprehension has facilitated the identification of multiple molecular targets. These targets span diverse cellular components, such as signal transmission cascades, growth factor binding sites, vasculogenic pathways, and mitotic regulatory mechanisms. Furthermore, this progress has extended to advancements in drug delivery methodologies, broadening the scope of potential therapeutic interventions. Therefore, additional research is essential to pinpoint therapeutic targets better and assist in developing more precise therapies that can enhance outcomes for individuals with OC.

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Ethics approval

No applicable.

Data availability

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Authors' contribution

FTR contributed to the conception, design, writing of this review article and figures drawing. SN revised the review and submitted the final version of the manuscript.

Competing interests

None.

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