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The Role of Sentinel Lymph Node Mapping in Pelvic Gynecologic Cancers: A Systematic Review

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1. Abstract

1.1. Objective: To systematically assess the diagnostic performance, clinical relevance, and safety of Sentinel Lymph Node (SLN) mapping in pelvic gynecologic cancers, and to compare current evidence with international guideline recommendations.

1.2. Methods: A systematic review was conducted according to PRISMA 2020 guidelines. PubMed/MEDLINE, Web of Science, Embase, and CENTRAL were searched for studies published between January 2000 and March 2025. Eligible studies included original clinical research evaluating SLN mapping in adult women with cervical, endometrial, ovarian, or vulvar cancers and reporting diagnostic, oncologic, or morbidity outcomes. Study selection, data extraction, and risk-of-bias assessment were performed independently by two reviewers. Due to clinical and methodological heterogeneity, results were synthesized narratively.

1.3. Results: 16 studies met the inclusion criteria. Evidence was strongest for early-stage cervical and endometrial cancers, where SLN mapping (particularly using indocyanine green fluorescence) demonstrated high diagnostic performance and was associated with reduced surgical morbidity compared with systematic lymphadenectomy. Ultrastaging increased detection of low-volume nodal disease, although its prognostic significance remained uncertain. Evidence in ovarian cancer was limited and primarily feasibility-based. Across studies, SLN mapping was consistently associated with lower rates of long-term complications, including lymphedema.

1.4. Conclusion: SLN mapping is a reliable and less morbid nodal staging strategy in selected cervical and endometrial cancers, while its role in ovarian cancer remains investigational. Further standardized and prospective research is required.

2. Introduction

Pelvic gynecologic cancers, including cervical, endometrial, ovarian, and vulvar malignancies, represent a major global health burden and account for a substantial proportion of cancer-related morbidity and mortality among women worldwide. Accurate staging is a cornerstone of their management, as it directly influences prognostic stratification, therapeutic decision-making, and survival outcomes. Among all staging parameters, lymph node status consistently emerges as one of the strongest independent prognostic factors across gynecologic malignancies [1,2]. Historically, systematic pelvic and para-aortic lymphadenectomy has been considered the gold standard for nodal staging. This approach allows comprehensive pathological assessment of nodal involvement but is associated with significant perioperative and long-term morbidity. Reported complications include lymphocele formation, lower-extremity lymphedema, vascular and neural injuries, prolonged operative time, and persistent impairment of quality of life [3,4]. Importantly, the oncological benefit of systematic lymphadenectomy has been increasingly questioned, particularly in early-stage endometrial cancer. Large retrospective studies and randomized trials have failed to demonstrate a consistent survival advantage associated with routine lymphadenectomy in low- and intermediate-risk disease, despite its well-documented morbidity [3,5]. These findings have fueled a paradigm shift toward surgical de-escalation strategies that aim to preserve oncologic safety while minimizing treatment-related harm. Within this evolving clinical context, Sentinel Lymph Node (SLN) mapping has emerged as an attractive alternative to systematic lymphadenectomy, offering a more targeted approach to nodal staging in pelvic gynecologic cancers. The concept of sentinel lymph node mapping is based on the biological principle that lymphatic drainage from a primary tumor follows an orderly and predictable pathway. The first lymph node(s) receiving drainage from the tumor the sentinel lymph node(s) are therefore most likely to harbor metastatic disease. If the sentinel node is free of metastasis, the probability of involvement of downstream non-sentinel nodes is presumed to be low. This concept was initially validated in melanoma and breast cancer, where SLN biopsy demonstrated high sensitivity and negative predictive value, leading to its adoption as a standard staging procedure. Its extension to gynecologic oncology has been facilitated by advances in surgical techniques, tracer technologies, and pathological ultrastaging [2]. In cervical and endometrial cancers, SLN mapping offers several clinically meaningful advantages. First, it enables accurate nodal staging while significantly reducing surgical morbidity compared with systematic lymphadenectomy [4]. Second, the use of ultrastaging techniques allows enhanced detection of low-volume metastases, including micrometastases and isolated tumor cells, which may be missed by conventional histopathological examination [1]. Third, SLN mapping supports a more individualized surgical approach by potentially sparing node-negative patients from unnecessary extensive nodal dissection. The introduction of Indocyanine Green (ICG) fluorescence imaging has further strengthened the rationale for SLN mapping. Compared with blue dyes and radiocolloids, ICG has been shown to improve overall and bilateral detection rates, particularly in minimally invasive surgery, thereby increasing the reliability and reproducibility of the technique [2,4]. As a result, SLN mapping has been progressively incorporated into international guidelines for selected patient populations. Despite its increasing adoption, the role of SLN mapping in pelvic gynecologic cancers remains subject to ongoing debate, and several important controversies persist. One major concern relates to diagnostic performance. Although high detection rates and low false-negative rates have been reported in early-stage cervical cancer, outcomes vary depending on tumor size, stage, tracer used, surgical expertise, and adherence to standardized mapping algorithms [2]. Mapping failure and unilateral detection remain clinically relevant issues, raising questions about optimal management strategies in these situations. Another unresolved issue concerns the clinical significance of low-volume nodal metastases detected through ultrastaging. While micrometastases and isolated tumor cells are increasingly identified with SLN techniques, their prognostic impact and implications for adjuvant therapy remain incompletely defined, particularly in endometrial cancer [5]. This uncertainty contributes to variability in clinical practice and guideline recommendations. Furthermore, although SLN mapping is well established in cervical and endometrial cancers, its role in ovarian cancer remains largely investigational. Existing studies are limited by small sample sizes, heterogeneous methodologies, and a lack of long-term oncologic outcomes, precluding definitive conclusions regarding safety and effectiveness. Finally, discrepancies among international guidelines (such as those issued by ESGO, NCCN, and FIGO) reflect differences in evidence interpretation and highlight the need for a comprehensive, systematic synthesis of available data to inform clinical decision-making. The primary objective of this systematic review is to critically evaluate the diagnostic performance and clinical validity of sentinel lymph node mapping in pelvic gynecologic cancers.

The secondary objectives are:

1. To compare sentinel lymph node detection techniques and pathological assessment strategies.
2. To assess oncological outcomes, including disease-free survival and overall survival.
3. To evaluate surgical morbidity and quality-of-life outcomes associated with SLN mapping compared with systematic lymphadenectomy.
4. To identify current limitations, unresolved controversies, and future research directions.

By synthesizing the existing evidence in accordance with PRISMA 2020 guidelines, this review aims to clarify the current role of SLN mapping in pelvic gynecologic oncology and provide a robust scientific basis for clinical practice and future research.

3. Methods

3.1. Protocol registration and reporting standards

This systematic review was designed and conducted in strict accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement, which provides updated methodological and reporting standards to enhance transparency, reproducibility, and methodological rigor in evidence synthesis [6]. A predefined review protocol was developed a priori to minimize the risk of selective reporting, analytical bias, and post hoc methodological modifications. The protocol specifies the research objectives, eligibility criteria, search strategy, outcomes of interest, and planned methods for data extraction, quality assessment, and synthesis. In line with best practices for systematic reviews in clinical research, the protocol was intended for registration in the International Prospective Register of Systematic Reviews (PROSPERO), an open-access database designed to promote methodological transparency and reduce unnecessary duplication of research [7]. Adherence to PRISMA 2020 recommendations guided all stages of the review process, including literature identification, study selection, data extraction, risk-of-bias assessment, and synthesis of results. The PRISMA 2020 checklist was used as a reporting framework to ensure that all essential methodological elements were explicitly described, thereby facilitating critical appraisal and reproducibility by readers and reviewers [6]. Any deviations from the registered protocol, should they occur, will be clearly documented and justified in the final manuscript, in accordance with PRISMA guidance. This methodological approach aligns with the standards required by leading journals in gynecologic oncology and evidence-based medicine and ensures a robust and transparent synthesis of the available literature on sentinel lymph node mapping in pelvic gynecologic cancers.

3.2. Research question and PICO framework

The research question of this systematic review was formulated a priori using the PICO framework (Population, Intervention, Comparator, Outcomes), a methodological tool widely recommended to ensure clarity, clinical relevance, and reproducibility in evidence-based research [8]. The primary research question was: What is the diagnostic performance, oncological safety, and clinical relevance of sentinel lymph node mapping compared with systematic lymphadenectomy or alternative nodal assessment strategies in pelvic gynecologic cancers? The PICO components guiding the review are summarized in [Table 1]. This structured framework ensured that clinically meaningful outcomes were prioritized while allowing for stratified analyses according to tumor type, disease stage, and SLN detection technique. The PICO framework also directly informed the literature search strategy and data extraction process.

Table 1: PICO framework for the systematic review

Component	*Definition*
Population (P)	Adult women diagnosed with pelvic gynecologic malignancies (cervical, endometrial, ovarian, and vulvar cancers) for whom nodal staging was clinically indicated
Intervention (I)	Sentinel Lymph Node (SLN) mapping and biopsy using any detection technique (blue dye, radiocolloid, indocyanine green, or combinations), with or without pathological ultrastaging
Comparator (C)	Systematic pelvic and/or para-aortic lymphadenectomy, alternative nodal staging strategies, or absence of nodal assessment
Primary Outcomes (O)	SLN detection rate, bilateral mapping rate, sensitivity, specificity, false-negative rate
Secondary Outcomes (O)	Disease-free survival, overall survival, recurrence patterns, surgical morbidity (lymphocele, lymphedema), perioperative complications, quality-of-life outcomes

3.3. Literature search strategy

A comprehensive and systematic literature search was conducted to identify all relevant studies evaluating sentinel lymph node mapping in pelvic gynecologic cancers. The search strategy was developed in accordance with established methodological recommendations for systematic reviews to ensure maximal sensitivity and transparency [6,8].

Electronic searches were performed in the following databases:

- PubMed/MEDLINE
- Embase
- Cochrane Central Register of Controlled Trials (CENTRAL)
- Web of Science

The search included studies published between January 2000 and March 2025, corresponding to the period during which sentinel lymph node techniques were introduced and progressively implemented in gynecologic oncology. Only studies published in English were considered eligible.

The search strategy combined Medical Subject Headings (MeSH) and free-text terms related to sentinel lymph node mapping and pelvic gynecologic malignancies. A summary of the core search concepts and representative terms is presented in [Table 2]. Boolean operators ("AND", "OR") were applied to combine concepts, and database-specific syntax was adapted for each platform. Reference lists of included studies and relevant reviews were manually screened to identify additional eligible publications. When necessary, study authors were contacted to clarify methodological details or obtain missing data. The complete search strategy for each database was documented in detail to ensure reproducibility, in accordance with PRISMA 2020 reporting standards [6].

Table 2: Core search concepts and representative keywords

Concept	*MeSH terms and free-text keywords*
Sentinel lymph node	"sentinel lymph node", "sentinel node biopsy", "SLN mapping"
Gynecologic cancers	"gynecologic cancer", "cervical cancer", "endometrial cancer", "ovarian cancer", "vulvar cancer"
Nodal staging	"lymphadenectomy", "nodal staging", "pelvic lymph nodes", "para-aortic lymph nodes"
Detection techniques	"indocyanine green", "ICG", "blue dye", "radiocolloid", "fluorescence imaging"

Source: Developed according to PRISMA 2020 recommendations.

3.4. Eligibility criteria

Eligibility criteria were defined a priori to ensure a transparent, reproducible, and clinically relevant selection of studies. Criteria were established in accordance with PRISMA 2020 recommendations and methodological guidance from the Cochrane Handbook for Systematic Reviews of Interventions [6,8].

Studies were considered eligible for inclusion if they met all of the following criteria:

➔ **Population:** Studies including adult women diagnosed with pelvic gynecologic malignancies, specifically cervical, endometrial, ovarian, or vulvar cancers, in whom lymph node assessment was part of the staging or treatment strategy.

➔ **Intervention:** Evaluation of Sentinel Lymph Node (SLN) mapping and biopsy using any detection technique, including blue dye, radiocolloid tracers, Indocyanine Green (ICG), or combinations thereof, with or without pathological ultrastaging.

➔ **Study design:** Original clinical research studies, including randomized controlled trials, prospective cohort studies, and retrospective observational studies.

➔ **Outcomes:** Reporting at least one outcome of interest, such as SLN detection rate, diagnostic accuracy (sensitivity, specificity, false-negative rate), oncological outcomes (disease-free or overall survival), or surgical morbidity.

➔ **Publication characteristics:** Full-text articles published in peer-reviewed journals, written in English, and available between January 2000 and March 2025.

Studies were excluded if they met any of the following criteria:

➔ **Study type:** Case reports, small case series (fewer than 10 patients), narrative reviews, systematic reviews, meta-analyses, editorials, commentaries, conference abstracts without full-text availability, and expert opinions.

➔ **Population:** Studies conducted exclusively in pediatric populations or animal models.

➔ **Intervention:** Studies not specifically evaluating sentinel lymph node mapping or those focusing solely on imaging-based nodal assessment without surgical SLN biopsy.

➔ **Data quality:** Studies with insufficient methodological detail, irretrievable or incomplete outcome data, or unclear definition of SLN mapping techniques.

➔ **Language and accessibility:** Non-English publications or studies for which the full text was not accessible.

3.5. Study selection process

The study selection process was conducted in accordance with PRISMA 2020 recommendations to ensure transparency, reproducibility, and minimization of selection bias [6]. All records identified through database searches were imported into a reference management software, and duplicate records were removed prior to screening. Study selection was performed in two sequential phases by two independent reviewers with expertise in gynecologic oncology and systematic review methodology. In the first phase, titles and abstracts were screened to exclude clearly irrelevant studies based on the predefined eligibility criteria. In the second phase, full-text articles of potentially eligible studies were retrieved and assessed in detail for final inclusion. Discrepancies between reviewers at any stage of the selection process were resolved through discussion and consensus. When agreement could not be reached, a third senior reviewer was consulted to arbitrate. Reasons for exclusion at the full-text screening stage were systematically documented to ensure traceability and methodological transparency. The overall selection process is reported using a PRISMA flow diagram, detailing the number of records identified, screened, excluded, and included, as well as reasons for exclusion at each stage, in accordance with PRISMA 2020 standards [6].

3.6. Data extraction

Data extraction was performed using a standardized and pilot-tested data extraction form, developed a priori to ensure consistency and completeness across included studies, in line with Cochrane methodological guidance [8]. Two reviewers independently extracted data from all included studies. Extracted information was subsequently cross-checked for accuracy and completeness. Any discrepancies were resolved by consensus, with consultation of a third reviewer when necessary. When relevant data were missing or unclear, corresponding authors were contacted for clarification whenever possible. The extracted data encompassed study characteristics, patient demographics, tumor features, details of the sentinel lymph node mapping technique, pathological assessment methods, and reported outcomes. A summary of the extracted variables is provided in [Table 3]. This structured approach facilitated systematic synthesis of heterogeneous data while enabling stratified analyses by cancer type, disease stage, and SLN detection technique.

Table 3: Data extraction variables

Category	*Extracted variables*
Study characteristics	Author(s), year of publication, country, study design, study period
Population	Sample size, age, cancer type, FIGO stage, risk classification
Intervention	SLN detection technique (ICG, blue dye, radiocolloid), injection site, surgical approach
Pathology	Use of ultrastaging, definition of micrometastases and isolated tumor cells
Comparator	Type and extent of lymphadenectomy or alternative nodal assessment
Diagnostic outcomes	Detection rate, bilateral mapping rate, sensitivity, specificity, false-negative rate
Oncologic outcomes	Disease-free survival, overall survival, recurrence patterns
Safety outcomes	Intraoperative complications, postoperative morbidity, lymphedema
Follow-up	Duration of follow-up, loss to follow-up

3.7. Risk of bias and quality assessment

The methodological quality and risk of bias of all included studies were independently assessed by two reviewers using validated tools tailored to the specific study designs, in accordance with PRISMA 2020 recommendations and the Cochrane Handbook for Systematic Reviews of Interventions [6,8]. For randomized controlled trials, the Cochrane Risk of Bias tool version 2.0 (RoB 2.0) was applied. This tool evaluates potential bias across five core domains: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in outcome measurement, and bias in selective reporting of results. Each domain was rated as presenting a low risk of bias, some concerns, or a high risk of bias, leading to an overall judgment for each study [9]. For non-randomized studies, including prospective and retrospective observational cohorts, methodological quality was assessed using the Newcastle–Ottawa Scale (NOS). This scale examines three main dimensions: the selection of study groups, the comparability of cohorts, and the ascertainment of outcomes. Studies were categorized according to their overall methodological quality based on established scoring thresholds [10]. Any discrepancies between reviewers regarding risk-of-bias judgments were resolved through discussion and consensus. When necessary, a third senior reviewer was consulted to arbitrate. The results of the quality assessment were considered during data synthesis and interpretation, and sensitivity analyses were planned to evaluate the robustness of findings by excluding studies deemed to be at high risk of bias.

3.8. Data synthesis and statistical analysis

Data synthesis was conducted using a structured and predefined analytical approach, combining qualitative narrative synthesis with quantitative meta-analysis when appropriate. This methodology follows established recommendations for systematic reviews of diagnostic and interventional studies in clinical research [8]. Initially, all included studies were synthesized narratively. Results were organized and interpreted according to cancer type (cervical, endometrial, ovarian, and vulvar), disease stage, sentinel lymph node detection technique, and pathological assessment strategy. This qualitative synthesis allowed identification of trends, consistencies, and discrepancies across studies, as well as contextualization of findings within the broader clinical and methodological landscape. Quantitative synthesis was planned when sufficient clinical and methodological homogeneity was observed. Pooled estimates were calculated for key diagnostic performance outcomes, including sentinel lymph node detection rate, sensitivity, specificity, and false-negative rate. For oncological outcomes, effect estimates such as hazard ratios with corresponding 95% confidence intervals were extracted directly from the studies or calculated when feasible. Statistical heterogeneity was assessed using the I^2 statistic, with increasing values indicating greater heterogeneity among studies. In the presence of moderate to substantial heterogeneity, a random-effects model was applied, whereas a fixed-effects model was considered when heterogeneity was minimal. Prespecified subgroup analyses were conducted based on cancer type, sentinel lymph node detection technique (particularly indocyanine green versus non-indocyanine green methods) the use of pathological ultrastaging, and study design. Sensitivity analyses were performed by excluding studies with a high risk of bias to assess the stability of the pooled results. When a sufficient number of studies were available for a given outcome, publication bias was evaluated using funnel plot asymmetry and formal statistical testing, such as Egger's regression test.

4. Results

4.1. Study selection and characteristics

The literature search identified a total of 248 records through electronic database searching, including PubMed/MEDLINE (n = 152), Web of Science (n = 64), Embase (n = 21), and the Cochrane Central Register of Controlled Trials (CENTRAL) (n = 11). After removal of duplicate records, 221 unique references remained for screening. Title and abstract screening was performed for 221 records, of which 143 were excluded for predefined reasons. The most common reasons for exclusion at this stage were lack of relevance to sentinel lymph node mapping, absence of focus on pelvic gynecologic cancers, and non-original study designs, including reviews and editorial articles. A total of 78 full-text articles were subsequently assessed for eligibility. Following full-text evaluation, 62 articles were excluded, primarily due to inappropriate study population, insufficient methodological detail, lack of extractable outcomes, or irrelevance to the review objectives. Ultimately, 16 studies met all inclusion criteria and were included in the qualitative synthesis of this systematic review. The complete study selection process is summarized in the PRISMA 2020 flow diagram [Figure 1]. The included studies represented a heterogeneous body of evidence reflecting the current clinical use and ongoing evaluation of sentinel lymph node mapping in pelvic gynecologic oncology. Most studies were observational in design, comprising prospective and retrospective cohort studies, with a smaller proportion of randomized or quasi-randomized investigations. Cervical and endometrial cancers accounted for the majority of included studies, predominantly in early-stage disease where nodal staging is of greatest clinical relevance. Studies were mainly conducted in specialized gynecologic oncology centers, reflecting clinical settings with established expertise in sentinel lymph node mapping techniques. Considerable variability was observed across studies with respect to detection techniques, pathological assessment protocols, and outcome reporting, which was taken into account in the subsequent synthesis of results.

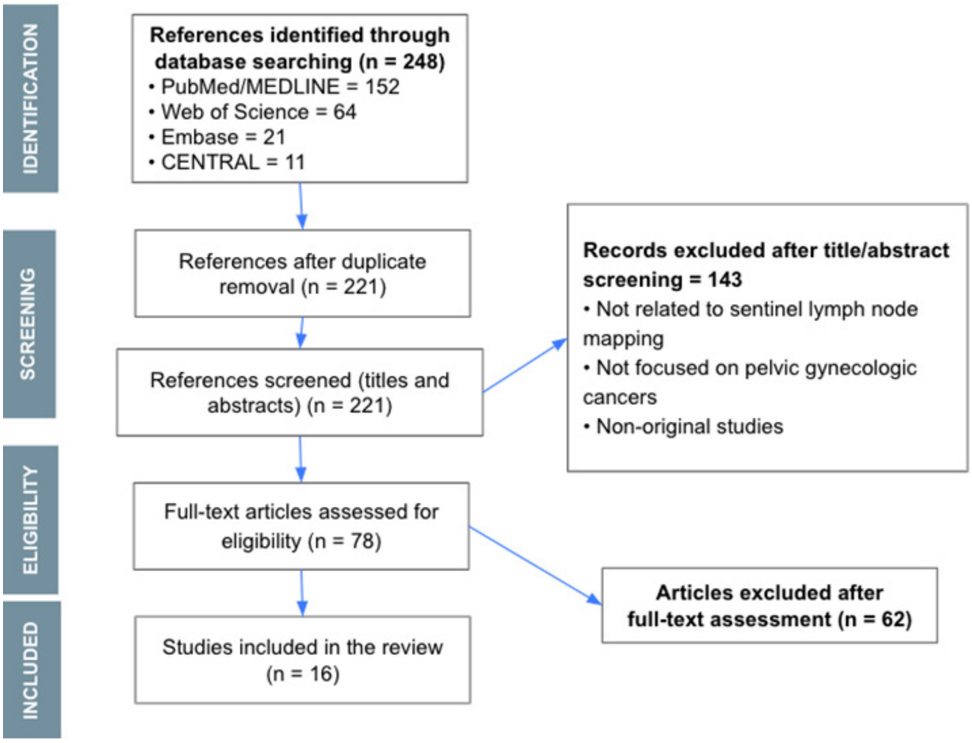

Figure 1: PRISMA 2020 flow diagram of study selection
Source: Authors' work (PRISMA 2020 template).

4.2. Sentinel lymph node mapping by cancer type

4.2.1. Cervical cancer: Sentinel lymph node mapping has been most extensively studied and clinically validated in cervical cancer, particularly in patients with early-stage disease. Across the included studies, SLN mapping demonstrated high overall detection rates, frequently exceeding 85–90%, with bilateral detection rates improving substantially in more recent series employing Indocyanine Green (ICG) fluorescence imaging [11]. Large prospective multicenter trials have provided robust evidence regarding diagnostic accuracy. The Gynecologic Oncology Group study led by Levenback et al. reported high sensitivity and a low false-negative rate in patients with early-stage squamous cell carcinoma of the cervix, particularly when SLN mapping algorithms were strictly followed [11]. Similarly, European multicenter studies confirmed that adherence to standardized SLN protocols (including side-specific lymphadenectomy in cases of mapping failure) significantly reduced false-negative rates [2]. Ultrastaging played a critical role in cervical cancer studies, allowing detection of low-volume nodal metastases that would have been missed by conventional histopathological examination. Several studies reported a non-negligible proportion of micrometastases and isolated tumor cells, highlighting the increased sensitivity of SLN-based nodal assessment [2,12]. Oncological outcomes reported in the included studies suggested that SLN mapping did not compromise disease-free or overall survival in appropriately selected patients with early-stage cervical cancer. However, long-term survival data remain limited, and most studies were not powered to detect small differences in survival outcomes.

4.2.2. Endometrial cancer: In endometrial cancer, sentinel lymph node mapping has been widely investigated as an alternative to systematic lymphadenectomy, particularly in low- and intermediate-risk disease. Across included studies, SLN mapping consistently demonstrated high detection rates, with ICG-based techniques achieving superior bilateral mapping compared with blue dye or radiocolloid methods [4,13]. Multiple cohort studies comparing SLN mapping with conventional lymphadenectomy reported similar oncological outcomes while significantly reducing surgical morbidity. Rossi et al. demonstrated that SLN biopsy provided comparable staging accuracy with fewer complications, including a reduced incidence of lymphocele formation and lower-extremity lymphedema [4]. The use of ultrastaging in endometrial cancer resulted in increased detection of low-volume nodal disease, particularly micrometastases. However, the prognostic significance of these findings remains controversial. Some studies suggested an association between micrometastases and increased recurrence risk, whereas others failed to demonstrate a clear impact on survival outcomes, contributing to heterogeneity in adjuvant treatment strategies [5,13]. Evidence regarding high-risk endometrial cancer is growing but remains less definitive. While feasibility and diagnostic accuracy have been demonstrated in selected high-risk populations, long-term oncological safety data are still limited.

4.2.3. Ovarian cancer: The role of sentinel lymph node mapping in ovarian cancer remains investigational. Compared with cervical and endometrial cancers, the number of included studies was limited, and sample sizes were generally small. Most studies focused on early-stage ovarian cancer and explored the feasibility of SLN mapping rather than its diagnostic accuracy or impact on oncological outcomes [14]. Detection rates varied widely across studies, reflecting differences in tracer type, injection site, and surgical technique. Reported approaches included injection into the ovarian ligaments or the ovarian hilum, with inconsistent success in identifying sentinel nodes. Methodological heterogeneity and lack of standardized protocols limited comparability across studies. Importantly, none of the included studies provided robust survival data or direct comparisons with systematic lymphadenectomy. As a result, the clinical utility of SLN mapping in ovarian cancer remains uncertain, and current evidence does not support its routine use outside of clinical trials or highly selected investigational settings.

4.2.4. Vulvar cancer: Sentinel lymph node mapping is well established in vulvar cancer and has been incorporated into standard clinical practice for patients with early-stage, unifocal disease. Although vulvar cancer is not strictly a pelvic malignancy, studies addressing pelvic nodal assessment were included selectively when relevant to the scope of this review. Landmark studies have demonstrated that SLN biopsy in vulvar cancer is associated with high sensitivity and low groin recurrence rates, leading to a paradigm shift away from routine inguinofemoral lymphadenectomy in eligible patients [15,16]. The reduction in surgical morbidity, particularly lymphedema and wound complications, has been substantial. While most vulvar cancer studies focus on inguinal rather than pelvic nodal assessment, the success of SLN mapping in this setting has contributed to broader acceptance of the technique across gynecologic oncology and has informed methodological approaches applied to pelvic malignancies.

4.3. Detection techniques

Across the included studies, Sentinel Lymph Node (SLN) detection techniques demonstrated considerable heterogeneity, reflecting both temporal evolution and differences in institutional practice. This heterogeneity concerned not only the type of tracer used, but also injection sites, dosages, and imaging modalities. Early investigations in pelvic gynecologic cancers predominantly relied on blue dye techniques, such as patent blue or isosulfan blue. While these methods were technically straightforward and widely available, their performance was inconsistent. Several studies reported acceptable overall detection rates but relatively low bilateral mapping rates, particularly in patients with higher body mass index or in anatomically complex pelvic regions [2,12]. In addition, limited tissue penetration and strong operator dependence were recurrent limitations, and rare allergic reactions were also described. The introduction of radiocolloid-based techniques, most commonly technetium-99m–labeled tracers, represented an important methodological advance. These techniques improved detection rates and enabled preoperative lymphoscintigraphy, allowing anatomical anticipation of sentinel node locations. However, their use was associated with several constraints, including the need for nuclear medicine infrastructure, exposure to ionizing radiation, and logistical complexity. As a result, radiocolloid techniques were primarily confined to specialized centers and were frequently combined with blue dye to enhance detection performance [2,11]. More recently, Indocyanine Green (ICG) fluorescence imaging has emerged as the dominant SLN detection modality across pelvic gynecologic cancers. Multiple prospective and retrospective studies consistently demonstrated that ICG provides superior overall and bilateral detection rates compared with blue dye and radiocolloid techniques, particularly in minimally invasive surgery [4,13]. The advantages of ICG include real-time visualization, deeper tissue penetration, and a favorable safety profile, which together contribute to greater reproducibility across surgeons and institutions.

Despite the widespread adoption of ICG, variability persisted across studies with regard to:

- injection sites (cervical, uterine, ovarian ligament),
- tracer concentration and volume,
- timing of injection relative to surgical dissection.

These methodological differences likely contributed to residual variability in reported detection outcomes and underscore the need for standardized SLN mapping protocols.

4.4. Surgical morbidity and safety

A consistent and clinically significant finding across the included studies was the reduction in surgical morbidity associated with sentinel lymph node mapping compared with systematic lymphadenectomy. This benefit was observed across different gynecologic cancer types and surgical approaches. Intraoperatively, SLN mapping was associated with shorter operative times and reduced blood loss compared with full pelvic and para-aortic lymphadenectomy. Several studies also reported fewer intraoperative complications, particularly vascular and nerve injuries, reflecting the more limited extent of dissection required for SLN biopsy [4,13]. Postoperative morbidity was also consistently reduced. Compared with systematic lymphadenectomy, SLN mapping resulted in lower rates of lymphocele formation, wound complications, and postoperative infections. These advantages were observed in both open and minimally invasive surgical settings. One of the most clinically relevant benefits of SLN mapping concerned long-term morbidity, particularly lower-extremity lymphedema. Studies with extended follow-up demonstrated a substantially lower incidence of chronic lymphedema in patients undergoing SLN biopsy alone, with important implications for long-term functional outcomes and quality of life [15,16]. From a safety perspective, adverse events directly attributable to SLN mapping were rare. Allergic reactions to tracers were infrequently reported, and serious complications related specifically to SLN biopsy were uncommon. Importantly, across studies in cervical and endometrial cancer, the reduction in surgical morbidity did not appear to compromise oncological safety. Recurrence patterns, disease-free survival, and overall survival were comparable between SLN mapping and lymphadenectomy groups, although most studies were not powered to detect small differences in survival outcomes [4,11]. Overall, these findings indicate that SLN mapping achieves a favorable balance between diagnostic accuracy and minimization of treatment-related morbidity when applied in appropriately selected patients.

5. Discussion

5.1. Principal findings

This systematic review synthesizes the available evidence on sentinel lymph node (SLN) mapping across pelvic gynecologic cancers and highlights several consistent and clinically relevant findings. First, SLN mapping demonstrates high diagnostic performance in early-stage cervical and endometrial cancers when standardized algorithms are applied. Detection rates and sensitivity were consistently high, particularly in studies employing indocyanine green (ICG) fluorescence imaging and adhering to side-specific completion lymphadenectomy in cases of mapping failure. These findings confirm that SLN mapping can provide reliable nodal staging while substantially reducing the extent of surgical dissection [2,4,11]. Second, the review underscores the central role of ultrastaging in enhancing the sensitivity of SLN mapping. Across cancer types, ultrastaging significantly increased the detection of low-volume nodal disease, including micrometastases and isolated tumor cells. While this represents a diagnostic advantage over conventional lymphadenectomy, the clinical implications of such findings remain incompletely defined, particularly in endometrial cancer. The absence of consensus regarding the prognostic significance of low-volume metastases continues to contribute to variability in adjuvant treatment strategies [2,5]. Third, one of the most robust findings of this review relates to surgical morbidity. Compared with systematic lymphadenectomy, SLN mapping was consistently associated with reduced operative time, lower blood loss, fewer perioperative complications, and a markedly lower incidence of long-term complications such as lower-extremity lymphedema. These benefits translate into improved functional outcomes and quality of life, without an apparent compromise in oncological safety in appropriately selected patients [4,15]. Fourth, the strength of evidence varied substantially across cancer types. While SLN mapping is supported by a large and relatively mature evidence base in cervical and endometrial cancers, data in ovarian cancer remain limited and largely exploratory. Available studies in ovarian cancer primarily addressed feasibility rather than diagnostic accuracy or survival outcomes, precluding firm conclusions regarding clinical utility [14,17]. Vulvar cancer, although not strictly pelvic, provided a proof of concept for SLN mapping, with long-term data supporting both safety and oncological effectiveness. Finally, this review highlights persistent methodological heterogeneity, including variability in detection techniques, injection sites, pathological protocols, and outcome reporting. This heterogeneity complicates cross-study comparisons and reinforces the need for standardized SLN mapping protocols and harmonized reporting standards.

5.2. Comparison with international guidelines

The findings of this systematic review are largely consistent with current international guideline recommendations, while also highlighting areas of ongoing debate and divergence.

Cervical cancer

International guidelines from the European Society of Gynaecological Oncology (ESGO) and the National Comprehensive Cancer Network (NCCN) endorse SLN mapping as an acceptable alternative to systematic pelvic lymphadenectomy in patients with early-stage cervical cancer, provided that validated mapping algorithms are followed [2,18]. The evidence synthesized in this review supports these recommendations, particularly regarding diagnostic accuracy and morbidity reduction. However, guideline caution regarding tumors larger than 2 cm and advanced-stage disease remains justified, given the limited high-quality evidence in these settings.

Endometrial cancer

Guideline recommendations in endometrial cancer are more nuanced. ESGO and ESMO guidelines recognize SLN mapping as a valid staging option in low- and intermediate-risk disease and increasingly support its use in selected high-risk histologies when performed in experienced centers [5,19]. The present review corroborates these positions, demonstrating comparable oncological outcomes and reduced morbidity compared with lymphadenectomy. Nevertheless, uncertainty persists regarding the management of low-volume nodal disease detected through ultrastaging, a point on which current guidelines remain deliberately non-prescriptive.

Ovarian cancer

No major international guideline currently recommends routine SLN mapping in ovarian cancer. Both ESGO and NCCN guidelines consider the technique investigational, reflecting the limited and heterogeneous nature of the available evidence [17,18]. The findings of this review strongly support this cautious stance, as robust data on diagnostic accuracy and survival outcomes are lacking.

Vulvar cancer

SLN mapping is firmly established in early-stage vulvar cancer and is strongly recommended by international guidelines. Although vulvar cancer lies partially outside the pelvic focus of this review, its inclusion provides an important methodological benchmark. The long-term safety data from vulvar cancer studies underpin the broader acceptance of SLN mapping principles in gynecologic oncology [15,16].

Overall, the evidence synthesized in this review aligns closely with contemporary guideline recommendations, supporting SLN mapping as a standard staging approach in selected pelvic gynecologic cancers while reinforcing the need for careful patient selection, standardized techniques, and continued high-quality research.

5.3. Clinical implications

The findings of this systematic review have several important implications for clinical practice in gynecologic oncology, particularly in the context of surgical decision-making and treatment individualization. First, the accumulated evidence supports sentinel lymph node mapping as a standard nodal staging strategy in carefully selected patients with early-stage cervical and endometrial cancers. When performed using validated algorithms and contemporary detection techniques (most notably indocyanine green fluorescence imaging) SLN mapping provides reliable staging information while substantially reducing surgical morbidity compared with systematic lymphadenectomy [4,11]. This balance between diagnostic accuracy and harm reduction aligns with current principles of value-based and patient-centered care. Second, SLN mapping facilitates surgical de-escalation without compromising oncological safety in appropriate clinical settings. The marked reduction in long-term complications, particularly lower-extremity lymphedema, has significant implications for survivorship and quality of life. These benefits are especially relevant given the increasing number of long-term survivors of gynecologic cancers and the growing emphasis on functional outcomes beyond survival alone [15,16]. Third, the routine use of pathological ultrastaging represents a double-edged sword. While it enhances diagnostic sensitivity and identifies low-volume nodal disease, it also introduces clinical uncertainty regarding optimal adjuvant treatment strategies. In the absence of definitive evidence on the prognostic impact of micrometastases and isolated tumor cells (particularly in endometrial cancer) clinical decision-making must remain individualized and multidisciplinary, integrating tumor biology, patient risk factors, and overall treatment goals [5,19]. Finally, the evidence synthesized in this review underscores the importance of experience and institutional expertise. SLN mapping is a technically demanding procedure with a learning curve, and its safe implementation requires adherence to standardized protocols, appropriate training, and close collaboration between surgeons, pathologists, and nuclear medicine specialists when applicable. Concentration of SLN mapping in specialized centers may therefore be essential to ensure optimal outcomes.

5.4. Limitations of the evidence

Several limitations inherent to the available literature must be acknowledged when interpreting the findings of this review. First, the overall evidence base is characterized by substantial methodological heterogeneity. Variability in study design, patient selection, detection techniques, injection sites, pathological protocols, and outcome definitions complicates cross-study comparisons and limits the strength of pooled conclusions. This heterogeneity is particularly pronounced in studies conducted over long time periods during which SLN techniques evolved rapidly. Second, most included studies were observational, with relatively few randomized controlled trials. Although prospective cohort studies provide valuable real-world data, they are inherently susceptible to selection bias and residual confounding. This limitation is especially relevant in comparisons between SLN mapping and systematic lymphadenectomy, where patient selection may be influenced by tumor characteristics or surgeon preference. Third, long-term oncological outcomes remain insufficiently reported in many studies. While short- and intermediate-term results suggest oncological safety in selected populations, most studies were not powered to detect small differences in disease-free or overall survival. This limitation is particularly relevant for high-risk endometrial cancer and for cancers in which SLN mapping remains investigational, such as ovarian cancer. Fourth, the clinical significance of low-volume nodal disease detected through ultrastaging remains unresolved. Inconsistent reporting and lack of standardized definitions further complicate interpretation, contributing to variability in adjuvant treatment decisions and guideline recommendations. Finally, publication bias cannot be excluded. Positive and feasibility-focused studies may be overrepresented, particularly in emerging fields such as SLN mapping in ovarian cancer.

5.5. Future perspectives

Future research should aim to address the identified evidence gaps and refine the clinical role of sentinel lymph node mapping in pelvic gynecologic cancers. First, there is a clear need for well-designed prospective trials, including randomized studies where feasible, to evaluate long-term oncological outcomes associated with SLN mapping compared with systematic lymphadenectomy. Such studies are particularly needed in high-risk endometrial cancer and in patient subgroups currently underrepresented in the literature. Second, standardization of SLN mapping protocols should be a research priority. Consensus on tracer type, injection site, pathological ultrastaging protocols, and reporting standards would enhance comparability across studies and facilitate evidence synthesis. International collaborative efforts and guideline-driven research frameworks may play a key role in this process. Third, further investigation is required to clarify the prognostic and therapeutic implications of low-volume nodal metastases. Defining whether micrometastases and isolated tumor cells should systematically influence adjuvant treatment decisions is essential to avoid both overtreatment and undertreatment. Fourth, emerging technologies may further transform SLN mapping. Advances in molecular pathology, imaging modalities, and artificial intelligence–assisted image analysis hold promise for improving detection accuracy, standardizing interpretation, and reducing interobserver variability. Integration of these technologies into SLN workflows represents an important avenue for future research. Finally, patient-reported outcomes and cost-effectiveness analyses should be incorporated into future studies to better inform policy decisions and guideline development in an era of constrained healthcare resources.

6. Conclusion

This systematic review provides a comprehensive synthesis of the current evidence regarding the role of Sentinel Lymph Node (SLN) mapping in pelvic gynecologic cancers. The findings support SLN mapping as a reliable and clinically meaningful nodal staging strategy in selected patient populations, particularly in early-stage cervical and endometrial cancers, where diagnostic accuracy is high and surgical morbidity is significantly reduced compared with systematic lymphadenectomy. When performed using validated algorithms, contemporary detection techniques (most notably indocyanine green fluorescence imaging) and standardized pathological ultrastaging, SLN mapping achieves an effective balance between oncological safety and minimization of treatment-related harm. The reduction in perioperative and long-term morbidity, especially lower-extremity lymphedema, has important implications for survivorship and quality of life. However, the strength of evidence varies across tumor types. While SLN mapping is supported by a mature and robust evidence base in cervical and endometrial cancers, its role in ovarian cancer remains investigational, and routine clinical implementation cannot be recommended outside of research settings. Persistent uncertainty regarding the prognostic significance of low-volume nodal disease detected through ultrastaging further highlights the need for individualized, multidisciplinary decision-making. Overall, SLN mapping represents a paradigm shift toward surgical de-escalation in gynecologic oncology. Continued efforts toward methodological standardization, high-quality prospective research, and long-term outcome reporting are essential to further refine its role and optimize patient selection across pelvic gynecologic malignancies.

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