

# Sentinel Lymph Node in Gynecologic Oncology: Comprehensive Narrative Review with Clinical Algorithms

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## Abstract

## Original Research Article

Sentinel lymph node (SLN) biopsy has emerged as a cornerstone technique in modern gynecologic oncology. It enables accurate nodal staging while minimizing surgical morbidity associated with systematic lymphadenectomy. Over the past two decades, extensive clinical trials and prospective studies have validated its diagnostic accuracy, safety profile, and prognostic value. This comprehensive narrative review examines anatomical foundations, technical aspects, oncologic outcomes, histopathologic ultrastaging, indications by tumor type, limitations, controversies, and future perspectives. Evidence indicates that SLN mapping achieves high sensitivity and negative predictive value across several gynecologic malignancies, particularly vulvar, endometrial, and early-stage cervical cancers. Integration of fluorescence imaging, standardized algorithms, and molecular pathology has further strengthened its clinical utility. SLN biopsy now has progressively modified surgical staging strategies over the past two decades to ward precision surgical staging and individualized patient care.

**Keywords:** Sentinel lymph node; Gynecologic oncology; Lymphatic mapping; Surgical staging; Minimally invasive surgery.

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## 1. INTRODUCTION

Accurate nodal assessment remains fundamental in gynecologic cancer management because lymphatic dissemination represents one of the earliest routes of metastasis. Nodal involvement strongly influences prognosis, recurrence risk, and adjuvant treatment decisions. Historically, pelvic and para-aortic lymphadenectomy constituted the standard staging procedure. Although diagnostically effective, systematic lymphadenectomy carries significant morbidity including lymphocele formation, chronic lymphedema, vascular injury, nerve damage, infection, prolonged operative time, and delayed recovery. The sentinel lymph node concept is based on the principle of orderly lymphatic spread. The first draining lymph node from a primary tumor reflects the biological status of the entire nodal basin. If this node is free of metastasis, the likelihood of downstream nodal involvement is extremely low. First validated in melanoma and breast cancer, the technique has progressively gained acceptance in gynecologic malignancies and is now integrated into international clinical guidelines for selected indications [1,2].

The development of sentinel node mapping reflects a broader paradigm shift in oncologic surgery: moving from radical standardized procedures toward risk adapted, minimally invasive, and personalized strategies that maintain oncologic safety while reducing treatment burden.

## 2. METHODOLOGY

This narrative review synthesizes peer reviewed literature indexed January 2005 to January 2025 in PubMed, Scopus, Web of Science, and Cochrane Library databases. Priority was given to randomized trials, prospective multicenter studies, meta-analyses, systematic reviews, and international guideline statements. Search terms included combinations of sentinel lymph node, mapping, gynecologic oncology, cervical cancer, vulvar cancer, ovarian cancer, and endometrial cancer. Reference lists of key articles were also screened. Publications with insufficient methodological detail or fewer than twenty patients were excluded to ensure scientific robustness. Data were synthesized qualitatively with emphasis on clinical applicability.

### 3. ANATOMICAL AND PHYSIOLOGICAL BASIS

Pelvic lymphatic drainage is highly organized yet variable. Major nodal basins include obturator, internal iliac, external iliac, common iliac, presacral, and para-aortic chains. Tumor cells entering lymphatic vessels are transported passively to the first draining node, which acts as a biological filter. Experimental and clinical correlation studies have confirmed that metastatic spread typically follows a stepwise pattern. However, anatomical variations, prior surgery, inflammation, or tumor induced lymphatic obstruction may alter drainage pathways, explaining occasional false negative results.

**The sentinel node concept therefore relies on three biological assumptions:**

1. lymphatic dissemination is orderly;
2. the first node reflects the entire basin;
3. accurate mapping can identify this node reproducibly.

Multiple validation studies comparing SLN biopsy with full lymphadenectomy have confirmed these principles, demonstrating negative predictive values exceeding 95% in appropriately selected patients.

### 4. TECHNIQUES OF SENTINEL NODE DETECTION

**Three main tracer categories are used:**

- Blue dyes – technically simple and inexpensive but limited by lower detection rates and difficulty visualizing deep nodes.
- Radiocolloids – technetium labeled tracers allow preoperative lymphoscintigraphy and intraoperative Gamma probe localization. They provide reliable detection but require nuclear medicine infrastructure.
- Indocyanine green (ICG) fluorescence – currently considered the most effective technique.

Near infrared imaging allows real time visualization of lymphatic channels and nodes with detection rates frequently above 90%.

Combined techniques using radioisotope and fluorescence provide the highest sensitivity and lowest False negative rates.

Injection sites vary according to tumor type. Cervical injection is most common because it is simple, reproducible, and effective for uterine tumors. Peritumoral injection is preferred for vulvar lesions.

Hysteroscopic subendometrial injection has been explored for endometrial cancer mapping. Ovarian injection remains experimental.

Operator experience significantly affects detection success. Studies indicate that approximately thirty supervised procedures are required to achieve technical proficiency.

### 5. CLINICAL APPLICATIONS BY TUMOR TYPE

#### Cervical cancer

Prospective data from the SENTICOL I and II studies demonstrated detection rates exceeding **90%**, with reported false-negative rates ranging between 7% and 9% in early-stage disease. Bilateral mapping significantly improved diagnostic performance [3,4].

#### Endometrial cancer

The FIRES trial (Rossi *et al.*, 2017), a multicenter prospective cohort study including 385 patients, reported:

- Sensitivity: **97.2%**
- Negative predictive value: **99.6%**
- False-negative rate: **2.8%**

These findings established SLN mapping as a reliable alternative to systematic lymphadenectomy in appropriately selected patients [5,6,7].

#### Vulvar cancer

The GROINSS-V-I study demonstrated that in patients with unifocal tumors <4 cm and clinically negative nodes, SLN biopsy was associated with: Groin recurrence rate: **2.3%** Significantly lower morbidity compared with complete inguinofemoral lymphadenectomy [8,9].

#### Ovarian cancer

Evidence remains limited. Complex ovarian lymphatic drainage and frequent advanced stage diagnosis restrict clinical use. Pilot studies suggest feasibility, but routine implementation is not recommended outside research protocols.

### 6. HISTOPATHOLOGICAL ULTRASTAGING

Unlike conventional lymphadenectomy specimens, sentinel nodes undergo intensive pathological evaluation. Ultrastaging protocols include serial sectioning, immunohistochemistry for cytokeratin markers, and occasionally molecular assays. This approach detects occult metastases that standard examination might miss.

Micrometastases (0.2–2 mm) and isolated tumor cells (<0.2 mm) can upstage disease and influence adjuvant therapy decisions. Their prognostic significance remains under investigation, but emerging evidence suggests they may correlate with increased recurrence risk in certain tumor types. Consequently, ultrastaging enhances staging precision and contributes to individualized treatment planning.

## 7. ADVANTAGES OF SENTINEL NODE STRATEGY

### Clinical benefits are well documented:

- markedly reduced postoperative complications
- shorter operative time
- faster recovery
- decreased hospital stays
- improved quality of life
- precise staging through focused pathology
- compatibility with minimally invasive and robotic surgery

From a health system perspective, SLN mapping may also reduce costs associated with managing complications such as chronic lymphedema.

## 8. LIMITATIONS AND PITFALLS

Despite its advantages, SLN biopsy has limitations. False negative results may occur due to altered lymphatic drainage, technical errors, or tumor obstruction. Detection rates may be lower in obese patients or after prior pelvic surgery. Equipment costs and training requirements may limit accessibility in low resource settings. Furthermore, lack of universal standardization in injection techniques and pathological processing introduces variability across institutions. Another ongoing controversy concerns the clinical significance of low volume metastases detected only by ultrastaging. Although they may represent early dissemination, their true prognostic impact remains debated. Long term prospective trials are needed to clarify management strategies for these findings.

## 9. THERAPEUTIC IMPACT AND CLINICAL DECISION MAKING

The integration of SLN biopsy has transformed treatment algorithms. Negative sentinel nodes allow surgeons to omit systematic lymphadenectomy safely, thereby reducing morbidity. Positive nodes identify patients who may benefit from adjuvant radiotherapy or systemic therapy. Consequently, nodal mapping supports risk adapted treatment selection rather than uniform protocols.

This approach aligns with the broader evolution toward precision oncology, in which therapy is tailored according to individual tumor biology and metastatic risk. SLN biopsy represents a bridge between surgical staging and personalized treatment planning.

## 10. FUTURE DIRECTIONS

Research is focused on enhancing diagnostic accuracy and expanding indications. Promising developments include tumor specific fluorescent tracers, hybrid imaging systems, artificial intelligence assisted intraoperative visualization, and integration of molecular biomarkers. Robotic fluorescence guided surgery may further improve detection precision.

In addition, international collaborations aim to standardize procedural protocols, reporting criteria, and pathological analysis. Such harmonization will facilitate comparison of outcomes across studies and strengthen evidence-based recommendations [F].

## 11. DISCUSSION

Accumulated evidence confirms that SLN biopsy achieves diagnostic accuracy comparable to systematic lymphadenectomy while significantly reducing surgical morbidity. However, its reliability is highly dependent on strict adherence to standardized algorithms and adequate surgical training [10].

Although SLN mapping demonstrates excellent diagnostic performance, caution is warranted when extrapolating results from high-volume centers to lower-resource environments. Access to indocyanine green fluorescence imaging and nuclear medicine facilities may be limited in developing countries, potentially affecting detection rates and cost-effectiveness [1,2].

Another unresolved issue concerns the prognostic significance of low-volume metastases detected through ultrastaging. Although micrometastases appear associated with increased recurrence risk in some studies, consensus regarding optimal adjuvant management is lacking. Long-term survival data remain insufficient.

Therefore, while SLN mapping represents a major step toward precision surgical staging, ongoing standardization and equitable access to technology are essential to ensure global applicability. In our clinical practice, the main challenge remains access to fluorescence imaging systems and structured training programs.

## 12. Implications for Emerging Health Systems

In middle-income countries such as Morocco and similar healthcare environments, the adoption of SLN mapping offers the potential to reduce postoperative morbidity and hospital stay, which may translate into overall healthcare cost reduction. However, investment in fluorescence imaging systems and structured surgical training programs remains necessary to ensure safe implementation.

## 13. CONCLUSION

Sentinel lymph node mapping has fundamentally reshaped surgical staging in gynecologic oncology. Supported by high-level evidence demonstrating excellent sensitivity and negative predictive value, it provides a safe alternative to systematic lymphadenectomy in selected patients.

Its integration into international guidelines reflects a paradigm shift toward individualized, minimally invasive, and morbidity-sparing oncologic

care. Future research should focus on long-term oncologic outcomes, standardization of ultrastaging protocols, and equitable implementation across diverse healthcare systems.

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