complex procedures. Particularly under the framework of enhanced recovery after surgery (ERAS), the demand for low trauma, high efficiency, and stable outcomes further elevates precision and standardization from technical goals to comprehensive quality management objectives (Vazquez et al., 2025).

4 Key Applications of AI in Minimally Invasive Gynecologic Surgery

4.1 Preoperative evaluation and individualized surgical planning

In minimally invasive gynecologic surgery, preoperative evaluation plays a critical role in determining the surgical approach, procedural selection, and risk management strategies. Traditional assessment relies primarily on ultrasound, CT, MRI, and surgeon experience; however, in cases such as deep infiltrating endometriosis, complex pelvic adhesions, and gynecologic malignancies, it is often difficult to precisely quantify lesion extent and its spatial relationship with critical structures such as the ureters, vessels, and bowel. In recent years, AI-driven imaging analysis tools have enabled the integration of clinical data, imaging information, and prior surgical records to achieve perioperative risk stratification and predict operative time, blood loss, length of hospital stay, and complication risk. These capabilities assist in selecting laparoscopic, robotic, or open approaches, thereby improving preoperative counseling and individualized decision-making (Chevalier et al., 2025; Osman et al., 2025; Pipes et al., 2025). For example, a decision tree–based model has been used to predict the feasibility and risk of single-port versus conventional laparoscopy, achieving an AUC of 0.77, highlighting the practical value of AI in personalized surgical approach selection.

Furthermore, AI-based image segmentation, radiomics, and three-dimensional reconstruction are advancing minimally invasive gynecologic surgery toward a “visualized planning” paradigm. AI-enhanced MRI, CT, and ultrasound analyses can differentiate benign from malignant adnexal masses, predict deep myometrial or cervical stromal invasion, and assess lymph node metastasis risk, thereby informing decisions regarding the extent of hysterectomy, lymphadenectomy, and fertility-sparing procedures (Paiboonborirak et al., 2025). In deep infiltrating endometriosis, AI-assisted 3D reconstruction models provide a clearer representation of lesion relationships with adjacent organs compared to traditional 2D imaging, facilitating surgical approach selection, dissection planning, and nerve preservation (Polat and Arslan, 2024). In the future, integrated models combining imaging, pathology, clinical variables, and prior outcomes may generate individualized “surgical roadmaps,” potentially evolving into platforms for preoperative virtual simulation and “digital twin”-based planning.

4.2 Intraoperative navigation and intelligent anatomical recognition

The intraoperative phase represents the most direct application scenario for AI, with its core function being the transformation of real-time surgical video into actionable navigation information. Deep learning-based computer vision models can analyze gynecologic laparoscopic videos in real time to perform organ classification and segmentation, identify critical anatomical structures, track instruments, and recognize surgical actions. Systematic reviews have demonstrated that such models achieve high accuracy in anatomical recognition, instrument tracking, and action identification, supporting their feasibility in procedures such as hysterectomy, myomectomy, and endometriosis surgery (Gkrozou et al., 2025). For high-risk structures such as the ureters, uterine arteries, and pelvic nerves, real-time AI-based labeling and alerts can reduce the likelihood of injury under conditions of complex adhesions or limited visualization, thereby improving intraoperative safety (Polat and Arslan, 2024).

Building on this, the integration of AI with augmented reality (AR) navigation further enhances intraoperative perception. By registering preoperative imaging and 3D models with the real-time surgical field, surgeons can access an “augmented view” that overlays anatomical information, tumor boundaries, and potential risk zones, enabling more precise resection and functional preservation in complex pelvic surgeries (Pavone et al., 2025). Additionally, AI can perform surgical phase recognition and workflow analysis. In a multicenter study of laparoscopic hysterectomy, AI models achieved 93% accuracy in identifying key procedural steps, providing a foundation for context-aware guidance, deviation alerts from standard workflows, and postoperative quality assessment (Leaf et al., 2024; Levin et al., 2024). Thus, AI-assisted intraoperative navigation extends beyond simple structure recognition, contributing to the development of an intelligent monitoring system aimed at improving safety, efficiency, and standardization.