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Artificial Intelligence-Assisted Minimally Invasive Gynecologic Surgery: Rationale and Clinical Context

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Abstract This study explores the current applications and clinical progress of artificial intelligence (AI)-assisted techniques in minimally invasive gynecologic surgery (MIGS). With the advancement of gynecologic surgery toward minimally invasive and precision-based approaches, conventional techniques still face limitations in complex anatomical recognition, operative precision, and standardization. AI technologies, by integrating preoperative imaging, intraoperative video, and multimodal clinical data, demonstrate significant potential in preoperative evaluation, individualized surgical planning, intraoperative navigation, robotic-assisted surgery, and surgical training. This study reviews the core technical foundations of AI and its primary application models in MIGS, with a particular focus on its potential to enhance surgical safety, accuracy, and efficiency. It also summarizes current challenges, including limited data scale, insufficient model generalizability, lack of high-quality clinical evidence, and ethical and regulatory concerns. Looking forward, with the advancement of multimodal data integration, digital surgery ecosystems, and multidisciplinary collaboration, AI is expected to further promote the evolution of gynecologic minimally invasive surgery toward precision, intelligence, and personalization. However, its widespread clinical implementation still depends on the establishment of standardized frameworks and validation through evidence-based medicine.

Keywords Artificial intelligence; Minimally invasive gynecologic surgery; Robotic surgery; Computer vision; Precision surgery

1 Introduction

In recent years, gynecologic surgery has gradually shifted from traditional open procedures toward minimally invasive approaches, forming a modern system of minimally invasive gynecologic surgery (MIGS) centered on laparoscopy, hysteroscopy, and robotic-assisted techniques. Various approaches, including conventional multiport laparoscopy, laparoendoscopic single-site surgery (LESS), vaginal natural orifice transluminal endoscopic surgery (vNOTES), and robotic-assisted surgery, have been widely applied in the diagnosis and treatment of uterine fibroids, endometriosis, ovarian tumors, and gynecologic malignancies such as endometrial cancer, and have progressively replaced laparotomy for many indications. Compared with open surgery, minimally invasive approaches offer significant advantages, including reduced intraoperative blood loss, lower perioperative complication rates, shorter hospital stays, less postoperative pain, and faster recovery. They also demonstrate important clinical value in preserving organ function, reducing postoperative adhesions, and improving quality of life (Ioana et al., 2024). In gynecologic oncology, studies have shown that, with appropriate patient selection, minimally invasive surgery can achieve oncologic outcomes comparable to open surgery, further establishing its central role in modern gynecologic practice. However, as procedural complexity increases and indications expand, minimally invasive surgery places higher demands on surgeons in terms of technical precision, spatial perception, and complex anatomical recognition. It is also associated with a steep learning curve and remains limited in areas such as deep infiltrating lesion identification, management of complex pelvic adhesions, and accurate tumor margin assessment (D'Augè et al., 2025).

At the same time, the rapid development of artificial intelligence (AI) has created new opportunities for transformation in surgical medicine. AI encompasses core technologies such as machine learning, deep learning, computer vision, and natural language processing, enabling complex pattern recognition and predictive analytics in medical data. These technologies are increasingly applied in imaging interpretation, risk assessment, clinical decision support, and surgical navigation (Luțenco et al., 2024; Varghese et al., 2024). In surgical settings, AI can