

standard of care for early-stage endometrial cancer and are increasingly applied in selected ovarian cancer staging and cytoreductive procedures, although their use in cervical cancer remains controversial, requiring stricter patient selection (Baba, 2024; Balafoutas and Vlahos, 2024; D'Augè et al., 2025).

In recent years, robotic-assisted surgery has emerged as an important direction in the development of MIGS. Compared with conventional laparoscopy, robotic platforms provide three-dimensional high-definition visualization, articulated instruments, multiple degrees of freedom, motion scaling, and tremor filtration, significantly enhancing flexibility and stability in deep pelvic, confined spaces, and complex anatomical regions. These advantages make robotic systems particularly suitable for technically demanding procedures such as deep infiltrating endometriosis resection, radical hysterectomy, and pelvic or para-aortic lymphadenectomy (Kang et al., 2024). Meanwhile, minimally invasive techniques continue to evolve toward “ultra-minimally invasive” approaches, including mini-laparoscopy and percutaneous “needlescopic” techniques using trocars of 3 mm or smaller, which reduce abdominal wall trauma while maintaining feasibility for complex procedures. Single-port surgery and vaginal natural orifice transluminal endoscopic surgery (vNOTES) further offer advantages in cosmetic outcomes and rapid recovery.

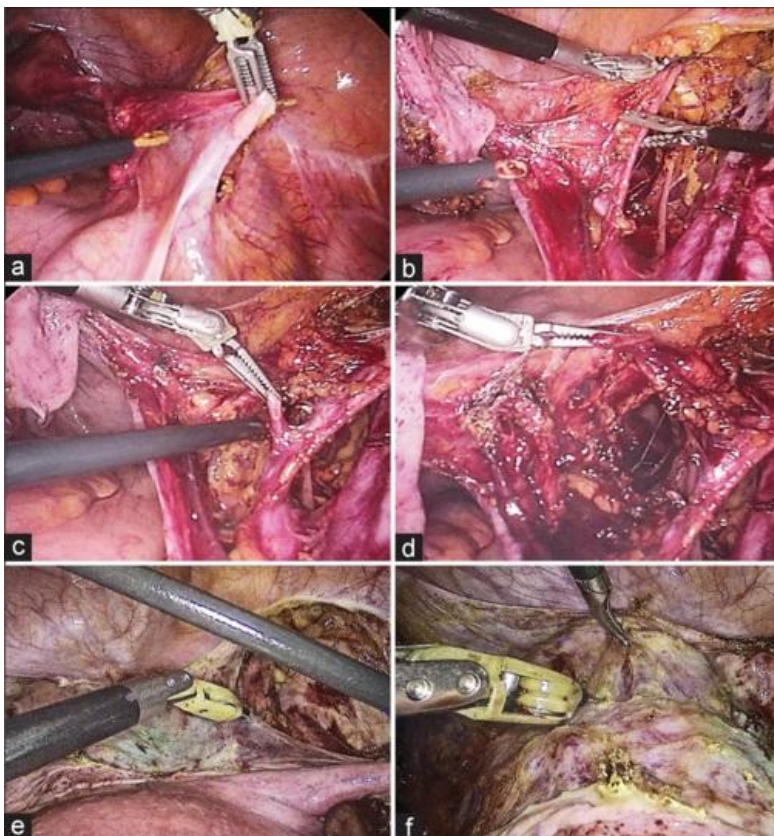


Figure 1 Intraoperative images showing technical advantages of articulation during gynecologic cancer surgery (Adopted from Pavone et al., 2025)

Image caption: (a-d) Fenestrated forceps, (e and f) Monopolar spatula (Adopted from Pavone et al., 2025)

3.2 Key challenges and limitations in surgical practice

Despite the advantages of MIGS, such as reduced trauma, faster recovery, and improved perioperative outcomes, it still faces several key challenges in clinical practice. From a technical perspective, conventional laparoscopy is limited by restricted instrument degrees of freedom, the fulcrum effect of long instruments, and difficulties in spatial perception under two-dimensional visualization. These limitations make complex suturing, deep pelvic dissection, and management of unexpected bleeding particularly challenging, especially for surgeons in the early stages of the learning curve. Although robotic systems improve visualization and instrument flexibility, issues such as lack of tactile feedback, instrument collisions, and spatial constraints in the narrow pelvis persist,