4.3 Integration of AI in robotic surgical systems

Robotic surgical platforms provide an ideal digital environment for AI integration, as they can simultaneously capture high-definition video, instrument kinematics, and system operation data, forming high-density multimodal datasets. Based on these data, AI has been applied to automatically analyze surgeon motion trajectories, smoothness, path efficiency, and motion redundancy, enabling objective assessment of surgical skills and correlation with expert evaluations and clinical outcomes (Knudsen et al., 2024). These tools can be embedded within robotic platforms to provide immediate postoperative feedback, long-term performance tracking, and personalized training design, thereby shortening the learning curve for complex procedures such as robotic radical hysterectomy or lymphadenectomy (Leaf et al., 2024).

Beyond assessment, AI is progressively transitioning toward assistive control within robotic systems. Currently, AI applications in robotic surgery mainly include intelligent camera control, tremor filtration, instrument path optimization, and semi-autonomous execution of specific subtasks such as suturing, knot tying, and local trajectory correction (Osman et al., 2025). Experimental studies have demonstrated that systems such as the Smart Tissue Autonomous Robot (STAR) can perform soft tissue recognition and automated suturing based on deep learning, suggesting the potential for task-level automation under strict supervision. Moreover, robotic platforms can integrate 3D reconstruction, augmented reality, intraoperative ultrasound, and fluorescence imaging, and AI-driven analysis of these multimodal data can enhance tumor localization, vascular identification, and margin assessment, thereby improving the safety of complex pelvic surgeries (Figure 2) (Pavone et al., 2025).

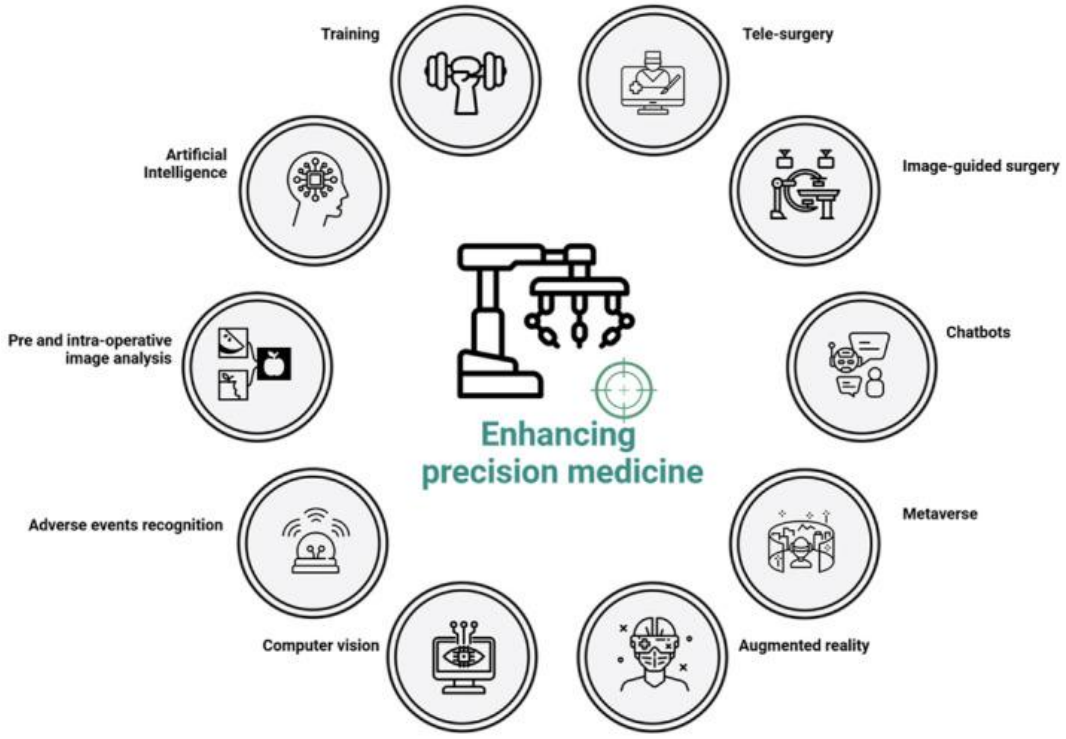

Figure 2 Potential benefits of robotic surgery: integration with new technologys (Adopted from Pavone et al., 2025)

5 Applications of AI in Surgical Training and Skill Assessment

5.1 Intelligent assessment systems based on surgical video

With the rapid digitalization of minimally invasive surgery, large volumes of high-quality laparoscopic and robotic surgical videos have provided a critical data foundation for AI-driven skill assessment. Using computer vision, deep learning, and other machine learning techniques, surgical videos can be automatically segmented, actions recognized, and semantic information extracted, enabling the quantification of spatiotemporal features such as operative time, instrument trajectory smoothness, motion redundancy, tissue handling precision, and workflow continuity (Power et al., 2025). Compared with traditional expert-based subjective scoring, these