including 3 436 patients reported that although AI shows promising potential in robotic surgery data analysis and prediction, there is still no conclusive evidence demonstrating a significant improvement in patient safety.

From an evidence-based medicine perspective, several limitations persist. Most AI models are trained on datasets of fewer than 1 000 cases, with limited external validation, restricting their robustness and generalizability. There is also substantial heterogeneity in study endpoints, evaluation metrics, algorithm architectures, and implementation methods, making cross-study comparisons difficult. Furthermore, studies focusing on long-term outcomes, such as recurrence rates, functional recovery, and quality of life, remain scarce. Therefore, although AI-assisted minimally invasive gynecologic surgery has demonstrated feasibility and multiple potential applications, it remains in a translational phase. Future progress will depend on multicenter, standardized studies with long-term follow-up to clarify its true clinical value and applicability boundaries (Brandão et al., 2024; Pipes et al., 2025).

6.3 Major challenges in data, algorithms, and ethics

Despite its significant potential, the clinical implementation of AI in minimally invasive gynecologic surgery is constrained by challenges related to data, algorithms, and ethical/legal considerations. From a data perspective, the availability of high-quality annotated datasets remains a major bottleneck. Most studies rely on small, single-center datasets with limited diversity in patient populations and equipment, resulting in insufficient generalizability across different clinical environments (Pipes et al., 2025). Additionally, gynecologic surgical video and imaging data are inherently complex and sensitive in terms of privacy, while standards for data collection, annotation, and storage are not yet unified, further complicating cross-study comparisons and external validation (Arakaki et al., 2024; Jeganathan et al., 2025).

At the algorithmic level, many current AI systems function as “black boxes” with decision-making processes that are difficult for clinicians to interpret and validate. This lack of transparency not only affects trust but also complicates physician–patient communication (Pipes et al., 2025). Moreover, issues such as imbalanced training data, labeling bias, and environmental variability may introduce algorithmic bias, while performance drift in real-world clinical settings can undermine reliability and reproducibility (Hmido et al., 2025). Consequently, explainability, robustness, continuous calibration, and external validation have become essential prerequisites for the safe deployment of AI in high-risk surgical scenarios.

Ethical and legal concerns are equally critical. The use of AI in surgery raises issues related to data privacy protection, informed consent for secondary data use, liability in cases of AI-assisted decision errors, and the potential erosion of surgical skills due to overreliance on technology (Jeganathan et al., 2025; Rad et al., 2025). As AI evolves from assistive analysis to semi-autonomous control, these concerns become even more pronounced. In addition, high costs, infrastructure requirements, and disparities in digital resources may concentrate advanced AI surgical systems in high-income regions and large medical centers, thereby exacerbating healthcare inequities (Osman et al., 2025; Wah, 2025). Therefore, advancing the standardized application of AI in minimally invasive gynecologic surgery requires not only technological innovation but also the establishment of robust data governance frameworks, ethical review systems, clear accountability mechanisms, and equitable implementation strategies.

7 Future Directions and Conclusion

In the future, AI-assisted minimally invasive gynecologic surgery will increasingly rely on multimodal data integration to achieve true precision surgery. Currently, robotic surgical platforms are capable of integrating endoscopic video, kinematic data, and system information, and combining them with preoperative MRI/CT, ultrasound, pathology, and genomic data to construct individualized surgical models. In gynecology, AI-enhanced imaging analysis and navigation technologies have been applied to the precise localization of endometrial cancer, sentinel lymph nodes, and submucosal fibroids, not only improving surgical targeting but also reducing operative time and intraoperative blood loss. Further integration with three-dimensional reconstruction, augmented reality, and robotic ultrasound is expected to optimize anatomical recognition, enhance surgical precision, and better protect critical structures.