

Advances in Multimodal Data Fusion for Intelligent Assessment and Digital Early Warning of Delayed Healing in Postoperative Perianal Wounds Following Anal Fistula Surgery: A Review

Xiyao Wang¹, Lin Hu^{2,*}

¹The First College of Clinical Medicine, Chongqing Medical University, Chongqing, China

²Colorectal Surgery, Liang Jiang Hospital of Chongqing Medical University, Chongqing, China

Email address:

1157887837@qq.com (Xiyao Wang), 2517899872@qq.com (Lin Hu)

*Corresponding author

Abstract

Postoperative wounds after anal fistula surgery are typically managed by secondary intention with open wound care, relying on granulation tissue formation and epithelialization. Due to the unique anatomical location, perianal wounds are susceptible to fecal contamination, high humidity, mechanical friction, sphincter movement, and frequent dressing changes. Consequently, some patients experience prolonged healing times, poor infection control, or stalled wound repair. Traditional wound assessment primarily depends on the TIME/TIMERS wound bed preparation frameworks and clinicians' subjective visual inspection. While these frameworks provide structured evaluation of tissue type, infection/inflammation, moisture balance, and wound edge status, they suffer from considerable subjectivity, limited quantification, poor continuity in home-based follow-up, and insufficient capability for early risk identification. Recent advances in medical image processing, deep learning, mobile health, and multimodal machine learning have opened new avenues for the digital assessment of open wounds. Existing studies have predominantly focused on diabetic foot ulcers, chronic leg ulcers, pressure injuries, burns, and general surgical wounds, where convolutional neural networks (CNNs), U-Net-based segmentation models, and Transformer architectures have been successfully applied for wound boundary detection, area measurement, tissue classification, and longitudinal monitoring. However, high-quality datasets, externally validated models, and prospective clinical studies specifically targeting open perianal wounds after anal fistula surgery remain scarce. Multimodal data fusion, which integrates wound images, symptom scores, defecation records, laboratory parameters, nutritional status, dressing compliance, and patient-reported outcomes, shows promise in constructing a more comprehensive postoperative risk assessment framework. Nevertheless, its predictive performance, clinical safety, and translational value in nursing practice require rigorous validation. This narrative review summarizes current evidence regarding risk factors for delayed healing of perianal wounds after anal fistula surgery, limitations of conventional assessment methods, advances in intelligent image recognition, multimodal data fusion strategies, digital early warning systems integrated with closed-loop continuity of care, and future challenges. Future research should prioritize the establishment of standardized anorectal wound databases, unified protocols for image acquisition and annotation, multicenter prospective validation studies, and enhanced model explainability, privacy protection, and clear definition of clinical responsibility. These efforts will provide a solid foundation for precision wound management and improved

continuity of care in patients undergoing anal fistula surgery.

Keywords

Anal Fistula, Delayed Wound Healing, Perianal Wound, Multimodal Data Fusion, Artificial Intelligence, Digital Early Warning, Continuity of Care