Chapter 11
Deep Learning–Enhanced Hyperspectral Imaging: Applications in Oncology Cancer Diagnosis and Tumor Margin Identification

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ABSTRACT

Hyperspectral Imaging (HSI) allows non-invasive, label-free, and highly accurate cancer diagnosis and tumor margin identification. By acquiring and analyzing detailed spectral and spatial information, HSI surpasses the capabilities of traditional imaging modalities. HSI is a robust tool for malignancy detection across diverse oncology domains, including head and neck, skin, and breast cancers. Deep learning (DL) for hyperspectral imaging demonstrates robust, high-accuracy performance for cancer diagnosis and tumor margin identification across oncology. Clinical validation studies frequently report better diagnostic accuracies, sensitivities, and specificities. The learning algorithms such as CNN and LDA attain the highest published metrics for real-time intraoperative and ex vivo assessment. DL applications for white blood cell classification and retinal imaging for diagnosing cardiovascular and metabolic diseases, illustrate the broader utility of these computational imaging approaches in healthcare.

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INTRODUCTION

Deep learning-enhanced hyperspectral imaging provides a non-invasive, label-free, and highly accurate approach for cancer diagnosis and tumor margin identification. Deep learning-enhanced hyperspectral imaging (HSI) demonstrates robust, high-accuracy performance for cancer diagnosis and tumor margin identification across oncology domains, including head and neck, skin, and breast cancers (Fang et al., 2025). It focuses on the intersection of optical engineering, advanced machine learning, and clinical oncology (Chou et al., 2025). Clinical validation studies frequently report diagnostic accuracies, sensitivities, and specificities exceeding 80%, with machine learning algorithms such as CNN and LDA attaining the highest published metrics for real-time intraoperative and ex vivo assessment. Its integration into clinical oncology is accelerating, driven by advances in AI, hardware, and clinical validation, with the promise of transforming cancer care in the coming years. The collected sources predominantly focus on the use of Hyperspectral Imaging (HSI), often combined with machine learning (ML) and deep learning (DL), as an advanced, non-invasive diagnostic and intraoperative tool in medical settings. HSI's application for tumour detection and margin delineation across various cancers, including brain, breast, skin, head and neck, and oesophageal, highlighting its ability to provide detailed spectral and spatial information beyond traditional imaging. (Saeed et al., 2026)

Figure 1. The operational challenges and information trade-offs against the HSI imaging modality currently embedded in conventional CT or MRI-based surgical workflow