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Clinical Radiology & Imaging Journal
ISSN: 2640-2343

Radiomics in Precision Oncology: Turning Medical Images into Quantitative Biomarkers

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Short communication

Volume 9 Issue 1

Received Date: May 11, 2025

Published Date: May 30, 2025

Abstract

Radiomics has emerged as an important approach for extracting quantitative information from medical images that may not be readily appreciated by visual assessment. By converting CT, MRI, and PET images into measurable features, radiomics can provide information related to tumor phenotype, heterogeneity, treatment response, and prognosis. Its potential role in precision oncology is particularly significant because conventional imaging interpretation often relies on qualitative descriptions and relatively limited measurable parameters. However, radiomics remains affected by variations in image acquisition, segmentation methods, feature extraction, and analytical pipelines. Reproducibility and external validation therefore remain essential before radiomic biomarkers can be routinely incorporated into clinical decision-making. Future progress will depend on standardized methodologies, multicentre validation, integration with clinical and molecular data, and prospective evaluation of patient benefit.

Keywords: Radiomics; Precision oncology; Medical imaging; Quantitative imaging; Biomarkers; Artificial intelligence

Introduction

Medical imaging has traditionally been used to identify, characterize, stage, and monitor tumors. Radiomics extends this role by treating images as quantitative datasets rather than simply visual representations. Through computational analysis, hundreds or thousands of features describing tumor intensity, texture, shape, spatial relationships, and heterogeneity can be extracted from routinely acquired images. These features may provide biological information that is not apparent during conventional image interpretation. The increasing interest in radiomics reflects a broader movement toward precision oncology. Instead of relying exclusively on tumor location, size, and morphology, radiomics aims to identify imaging-derived signatures associated with molecular characteristics, treatment response, recurrence, and survival [1].

Radiomics as a Source of Imaging Biomarkers

Tumor heterogeneity is a major challenge in cancer management. Two tumors with similar dimensions may demonstrate very different biological behavior and therapeutic responses. Radiomic analysis can quantify variations within a tumor and potentially identify patterns associated with aggressive disease. CT, MRI, and PET have all been investigated for radiomic applications. In oncology, radiomic features have been explored for diagnosis, tumor grading, prediction of treatment response, recurrence assessment, and survival estimation. Radiomics may therefore complement conventional imaging rather than replace established radiological assessment. The concept is

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particularly attractive in situations where repeated tissue sampling is difficult or provides information from only a small portion of a heterogeneous tumor. Imaging covers the entire lesion and can potentially be evaluated repeatedly during the course of treatment.

The Reproducibility Problem

Despite its promise, radiomics faces an important translational challenge: reproducibility. Radiomic features can be influenced by scanner characteristics, acquisition parameters, reconstruction algorithms, contrast administration, segmentation methods, and preprocessing techniques. Consequently, a model developed using one dataset may not perform similarly in another institution. This problem limits the reliability of radiomic biomarkers and makes comparison between studies difficult. Standardized acquisition protocols, robust segmentation strategies, feature harmonization, and transparent reporting are therefore necessary. External validation using independent patient populations should become a routine requirement before proposed radiomic biomarkers are considered clinically useful [2].

Combining Radiomics with Clinical and Molecular Data

The future of radiomics is unlikely to depend on imaging alone. Combining radiomic information with clinical variables, laboratory findings, pathology, genomics, and other biomarkers could provide a more comprehensive representation of tumor biology. This approach may be particularly valuable for developing predictive models that support individualized treatment selection. For example, imaging-derived characteristics could potentially be combined with molecular information to identify patients more likely to respond to a specific therapy. Such multimodal approaches could transform radiomics from an exploratory research technique into a component of integrated precision oncology [3].

From Research to Clinical Practice

The transition from promising radiomic models to routine clinical use requires stronger evidence. Many published studies are retrospective and based on relatively small, single-centre datasets. High-performing models may therefore reflect characteristics of the development population rather than universally applicable biological relationships. Future studies should prioritize prospective multicentre validation, standardized imaging protocols, reproducible computational pipelines, and clinically meaningful outcomes. Importantly, researchers should demonstrate whether radiomic information actually changes treatment decisions or improves patient outcomes rather than reporting predictive accuracy alone [4].

Conclusion

Radiomics provides an opportunity to transform medical images into quantitative biomarkers with potential applications throughout the cancer care pathway. Its ability to characterize tumor heterogeneity and generate predictive information makes it an attractive component of precision oncology. However, methodological variability and limited external validation continue to restrict clinical translation. Standardization, independent validation, and integration with clinical and molecular information will be essential for establishing radiomics as a reliable tool for personalized cancer care.

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