International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2025: 7.089

The Role of Radiogenomics in Adult Precision Medicine: A Systematic Review

Dr Smita Kachewar[1], Dr Swapnali Borade[2], Rahim Pathan[3]

[1]Consultant Oncopathologist, Deenanath Mangeshkar Hospital and Research Center, Erandawane Pune, India-411004
Corresponding Author Email: *smitakachewar[at]outlook.com*

[2]Fetal Medicine Consultant, Dr D.Y. Patil Hospital & Research Centre, Pune, India-411018 Independent Director; Research & Academic Head @ImagingInsights AI
Email: *swapnalirb[at]gmail.com*

[3]Director Innovation and Applications, Imaging Insight AI, Office C-659, Gera's Imperium Gateway, Near Bhosari Metro Station, Nashik Phata Flyover, Pune – 411034, India
Email: *info[at]imaginginsightai.com*

Abstract: ***Background:*** ***Radiogenomics integrates quantitative imaging features with genomic and molecular data to non-invasively characterise disease biology. In adult medicine, this approach has emerged as a powerful tool to address tumour heterogeneity, guide personalised therapy, and improve prognostication across multiple disease domains.*** ***Objective:*** ***To systematically review the global evidence on the clinical role, applications, and limitations of radiogenomics in adult populations.*** ***Methods:*** ***A systematic review of peer-reviewed literature was conducted following PRISMA guidelines. Studies evaluating associations between radiological features and genomic, transcriptomic, or molecular alterations in adult patients were included.*** ***Results:*** ***Radiogenomics has demonstrated robust correlations with key molecular pathways, driver mutations, tumour microenvironment characteristics, and clinical outcomes—particularly in oncology. Evidence supports its utility in treatment response prediction, survival stratification, and non-invasive molecular profiling.*** ***Conclusion:*** ***Radiogenomics is a validated and rapidly evolving pillar of adult precision medicine, with growing clinical relevance beyond oncology. Standardisation, prospective validation, and equitable global implementation remain key challenges.***

Keywords: radiogenomics, medical imaging biomarkers, precision medicine, tumour genetics, non-invasive diagnostics

1. Introduction

Precision medicine in adults requires accurate characterisation of disease heterogeneity at anatomical, functional, and molecular levels. While genomics has transformed disease classification and targeted therapy, its clinical application is limited by invasiveness, sampling bias, cost, and impracticality for longitudinal monitoring.**1**

Radiogenomics addresses these limitations by integrating high-throughput imaging features (radiomics) with genomic and molecular data, enabling non-invasive inference of underlying biology. Unlike traditional imaging interpretation, radiogenomics captures tumour phenotype at a whole-organ or whole-body level, reflecting spatial and temporal heterogeneity that single biopsies often miss.**2,3**

This systematic review evaluates the global evidence supporting radiogenomics in adult populations, focusing on clinical applications, methodological robustness, and translational impact.

2. Methods

2.1 Study Design

A systematic review was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.

2.2 Data Sources and Search Strategy

Peer-reviewed articles were identified from major biomedical databases (PubMed, Scopus, Web of Science) using combinations of the following terms:

- Radiogenomics
- Radiomics AND genomics
- Imaging biomarkers AND molecular profiling
- Adult oncology radiogenomics
- Only English-language studies involving adult patients (≥18 years) were included.

2.3 Inclusion and Exclusion Criteria

Inclusion criteria:

- Original research studies or high-quality systematic reviews
- Adult populations
- Correlation of imaging features with genomic, transcriptomic, epigenetic, or molecular alterations
- Clinical endpoints (diagnosis, prognosis, treatment response)

Exclusion criteria:

- Paediatric-only studies
- Animal or in-vitro studies
- Pure radiomics studies without molecular correlation
- Editorials and opinion pieces

2.4 Data Extraction and Synthesis

Data were extracted on:

- Disease type

- Imaging modality
- Genomic or molecular markers
- Clinical outcomes
- Validation methods

Given methodological heterogeneity, a qualitative synthesis was performed.

3. Results

3.1 Study Characteristics

The reviewed literature predominantly originated from North America, Europe, and East Asia, with growing contributions from low- and middle-income countries. Most studies focused on oncology, with additional evidence emerging in neurology and cardiovascular disease.

3.2 Radiogenomics in Adult Oncology

3.2.1 Brain Tumours

Radiogenomics has been most extensively validated in adult gliomas. MRI features have shown strong correlations with:

- IDH mutation status
- 1p/19q co-deletion
- MGMT promoter methylation

These imaging-genomic associations enable non-invasive molecular classification, prognostication, and treatment planning, particularly when biopsy is high-risk or infeasible. **4,5**

3.2.2 Lung Cancer

In non-small cell lung cancer (NSCLC), CT-based radiomic signatures have been associated with:

- EGFR mutations
- KRAS alterations
- PD-L1 expression

Radiogenomics has demonstrated potential in predicting response to targeted therapies and immunotherapy, supporting treatment selection without repeated tissue sampling.**6,7**

3.2.3 Breast Cancer

Radiogenomic studies in breast cancer have linked imaging phenotypes with:

- Hormone receptor status
- HER2 expression
- Molecular subtypes (luminal, HER2-enriched, basal-like)
- MRI-derived features have shown promise in predicting treatment response and recurrence risk.7,8

3.2.4 Renal and Hepatocellular Carcinoma

Radiogenomics has enabled differentiation of molecular subtypes, angiogenic activity, and tumour aggressiveness, supporting personalised therapeutic strategies in adult renal and liver cancers.**7**

3.3 Beyond Oncology

3.3.1 Neurology

In adult neurodegenerative disorders, early studies have correlated imaging biomarkers with genetic risk profiles, particularly in Alzheimer's disease and multiple sclerosis, aiding risk stratification and disease monitoring.**9**

3.3.2 Cardiovascular Disease

Emerging evidence suggests radiogenomics may help link imaging phenotypes of cardiomyopathies and atherosclerosis with inherited genetic variants, although clinical adoption remains early.**10**

3.4 Clinical Impact 11

Across adult populations, radiogenomics has demonstrated:

- Improved non-invasive molecular characterisation
- Enhanced risk stratification and prognosis
- Support for treatment selection and monitoring
- Reduction in unnecessary biopsies

4. Discussion

Radiogenomics represents a paradigm shift in adult precision medicine by transforming medical imaging into a surrogate for molecular profiling. Its greatest strength lies in capturing spatial heterogeneity and enabling longitudinal assessment-capabilities that conventional genomics alone cannot provide.

However, challenges remain:**8,11**

- Lack of standardised imaging protocols
- Variability in feature extraction and modelling
- Limited prospective, multi-centre validation
- Underrepresentation of diverse global populations

Addressing these limitations is essential for equitable and reproducible clinical translation.

5. Future Directions 1, 9, 11

Integration with AI and deep learning for automated feature extraction

- Multi-omics fusion (genomics, transcriptomics, proteomics)
- Large-scale, prospective adult cohorts
- Regulatory frameworks for clinical deployment
- Inclusion of underrepresented populations to avoid bias

6. Conclusion

Radiogenomics has matured into a scientifically robust and clinically relevant discipline in adult medicine. Strong global evidence supports its role in oncology and emerging applications beyond cancer. With continued standardisation, validation, and ethical implementation, radiogenomics is poised to become a cornerstone of adult precision healthcare worldwide.

Declarations

- Ethics approval and consent to participate: Waived Off as this is a review article.
- Consent for publication: No patient data or images used, hence not needed.
- Availability of data and materials: Freely available on the world wide web.
- Competing interests: No conflict of interest.
- Funding: No funding source is used for the article.

Authors' contributions: All authors have equally contributed and approved the final manuscript.

Acknowledgements: ImagingInsights AI for encouraging us.

References

[1] Zhang X, Lai Q, Cao J, Ching JCF, Teng X, Zhang J, Lee SWY, Ren G, Cai J. Radiogenomics: Current Understandings and Future Perspectives. MedComm (2020). 2026 Jan 22;7(2):e70583. doi: 10.1002/mco2.70583. PMID: 41583907; PMCID: PMC12828074.

[2] Karczewski K. J. and Snyder M. P., "Integrative Omics for Health and Disease," Nature Reviews Genetics 19, no. 5 (2018): 299–310.

[3] Lambin P., Rios-Velazquez E., Leijenaar R., et al., "Radiomics: Extracting More Information From Medical Images Using Advanced Feature Analysis," European Journal of Cancer 48, no. 4 (2012): 441–446.

[4] Bai J., Cui B., Li F., Han X., Yang H., and Lu J., "Multiparametric Radiomics Signature for Predicting Molecular Genotypes in Adult-type Diffuse Gliomas Utilizing 18F-FET PET/MRI," BMC Medical Imaging 25, no. 1 (2025): 187.

[5] Wroblewski T. H., Karabacak M., Seah C., Yong R. L., and Margetis K., "Radiomic Consensus Clustering in Glioblastoma and Association with Gene Expression Profiles," Cancers 16, no. 24 (2024): 4256.

[6] Sangeetha S. K., Mathivanan S. K., Karthikeyan P., et al., "An Enhanced Multimodal Fusion Deep Learning Neural Network for Lung Cancer Classification," Syst Soft Comput 6 (2024): 200068.

[7] Singh A, Chitalia R, Kontos D. Radiogenomics in brain, breast, and lung cancer: opportunities and challenges. J Med Imaging (Bellingham). 2021;8(3): 031907.

[8] Pinker K, Chin J, Melsaether AN, Morris EA, Moy L. Precision medicine and radiogenomics in breast cancer: new approaches toward diagnosis and treatment. Radiology. 2018;287(3):732–47.

[9] Yin T. T., Cao M. H., Yu J. C., et al., "T1-Weighted Imaging-Based Hippocampal Radiomics in the Diagnosis of Alzheimer's Disease," Academic Radiology 31, no. 12 (2024): 5183–5192.

[10] Polidori T., De Santis D., Rucci C., et al., "Radiomics Applications in Cardiac Imaging: A Comprehensive Review," La Radiologia Medica 128, no. 8 (2023): 922–933.

[11] Lambin P., Woodruff H. C., Mali S. A., et al., "Radiomics Quality Score 2.0: Towards Radiomics Readiness Levels and Clinical Translation for Personalized Medicine," Nature Reviews Clinical Oncology 22, no. 11 (2025): 831–846.