

Quantification in PET imaging and correlation with clinical data



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"Classical" quantification in PET: the role of SUV

The Standardized Uptake Value (SUV) is the most widely used semi-quantitative parameter in clinical practice to express tissue metabolic activity (e.g. 18F-FDG).

SUVmax

Maximum uptake value within the lesion: simple and reproducible, but sensitive to the statistical noise of a single voxel.

SUVmean

Mean uptake over the entire segmented volume: more stable, but dependent on segmentation quality.

MTV

Metabolic Tumor Volume: amount of metabolically active tissue, correlated with overall tumor burden.

TLG

Total Lesion Glycolysis: combines volume and metabolic intensity ($MTV \times SUV_{mean}$).

From a single value to texture: why we need radiomics

Limitations of classical quantification

- SUV and MTV summarize the lesion in a few numbers, ignoring the spatial heterogeneity of the tumor
- Variable sensitivity and non-specific uptake in inflammatory conditions (e.g. 18F-FDG)
- Limited ability to describe shape, texture and intratumoral distribution of metabolic activity

The radiomics answer

- + Converts the image into a high-dimensional feature space, mineable with statistical and ML methods
- + Describes shape, intensity and texture (e.g. entropy, homogeneity) beyond the single uptake value
- + Captures intratumoral heterogeneity, potentially predictive of prognosis and treatment response

What radiomic features measure

Shape

Volume, surface area, sphericity, compactness: they describe the geometry of the segmented lesion

Intensity (First order)

Mean, median, standard deviation, skewness of the distribution of uptake values

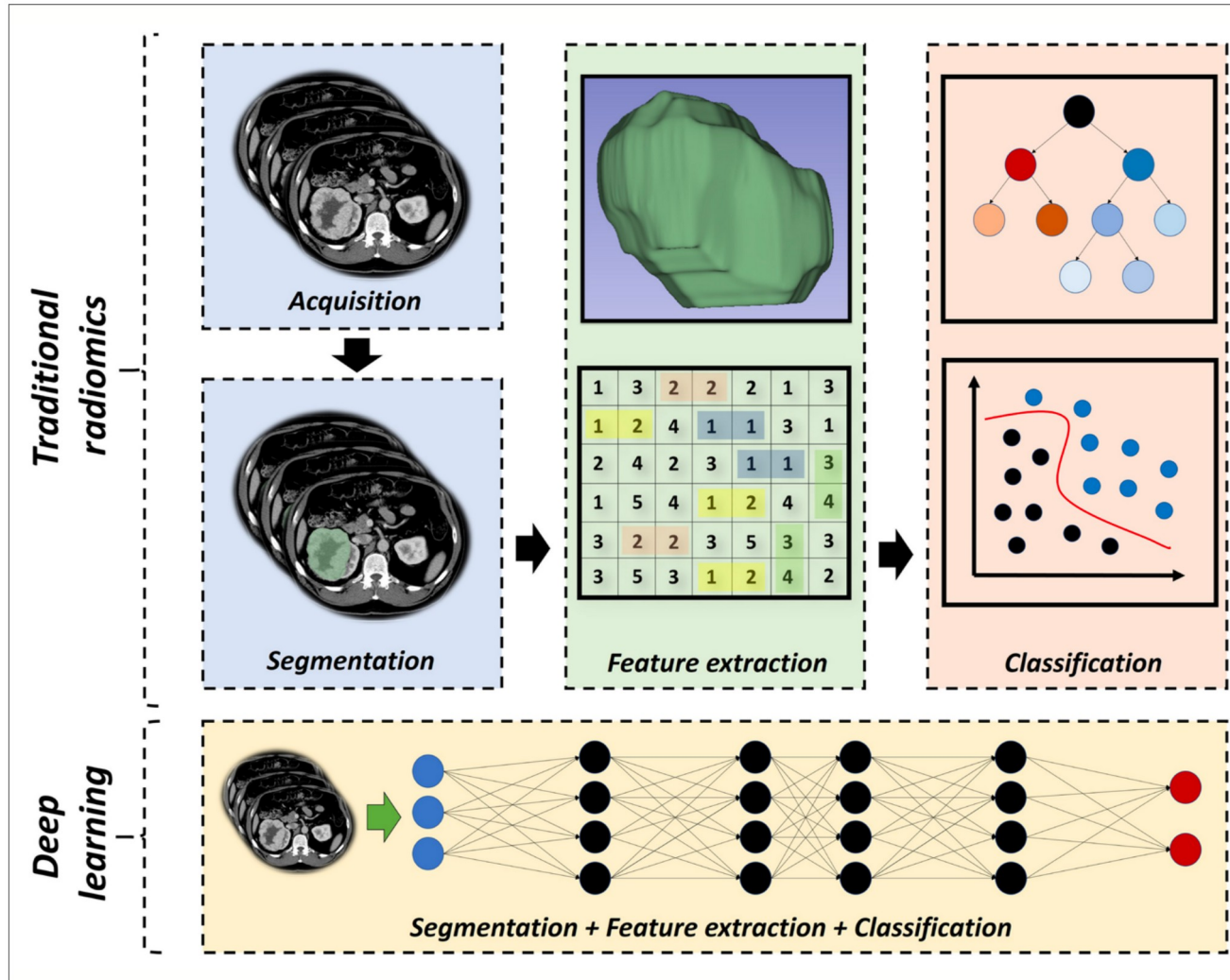
Texture (Second order)

Entropy, homogeneity, contrast: they quantify spatial patterns and intratumoral heterogeneity

Together, these features build a quantitative "signature" of the lesion, complementary to SUV and potentially more informative for the biological characterization of the tumor.

The radiomic workflow, step by step





Koçak B, Durmaz EŞ, Ateş E, Kılıçkesmez Ö.
Radiomics with artificial intelligence: a practical guide for beginners. Diagn Interv Radiol 2019; 25:485–495

Figure 2. Over-simplified representation of traditional and deep learning-based radiomics.



diagnostics



Article

Phenotyping the Histopathological Subtypes of Non-Small-Cell Lung Carcinoma: How Beneficial Is Radiomics?

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Non-small cell lung carcinoma histopathological subtype phenotyping using high-dimensional multinomial multiclass CT radiomics signature

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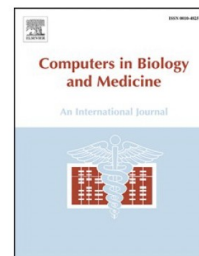
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Challenges and limitations in applying radiomics to PET imaging: Possible opportunities and avenues for research

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ABSTRACT

Radiomics, the high-throughput extraction of quantitative imaging features from medical images, holds immense potential for advancing precision medicine in oncology and beyond. While radiomics applied to positron emission tomography (PET) imaging offers unique insights into tumor biology and treatment response, it is imperative to elucidate the challenges and constraints inherent in this domain to facilitate their translation into clinical practice. This review examines the challenges and limitations of applying radiomics to PET imaging, synthesizing findings from the last five years (2019–2023) and highlights the significance of addressing these challenges to realize the full clinical potential of radiomics in oncology and molecular imaging. A comprehensive search was conducted across multiple electronic databases, including PubMed, Scopus, and Web of Science, using keywords relevant to radiomics issues in PET imaging. Only studies published in peer-reviewed journals were eligible for inclusion in this review. Although many studies have highlighted the potential of radiomics in predicting treatment response, assessing tumor heterogeneity, enabling risk stratification, and personalized therapy selection, various challenges regarding the practical implementation of the proposed models still need to be addressed. This review illustrates the challenges and limitations of radiomics in PET imaging across various cancer types, encompassing both phantom and clinical investigations. The analyzed studies highlight the importance of reproducible segmentation methods, standardized pre-processing and post-processing methodologies, and the need to create large multicenter studies registered in a centralized database to promote the continuous validation and clinical integration of radiomics into PET imaging.

7.0
Impact Factor

Metrics

11.7 CiteScore 2023 ⓘ 1.481 SJR 2023 ⓘ 1.706 SNIP 2023 ⓘ

CiteScore Rank ⓘ

ASJC Category	Quartile	Percentile	Rank
Computer Science Applications	Q1	91st	71 / 817
Health Informatics	Q1	89th	15 / 138



Article

matRadiomics: A Novel and Complete Radiomics Framework, from Image Visualization to Predictive Model

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matRadiomics

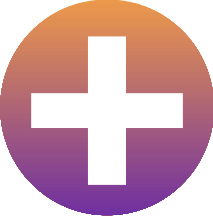
A complete radiomics freeware

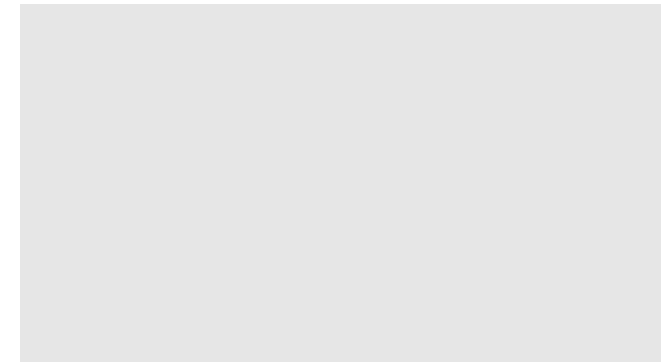
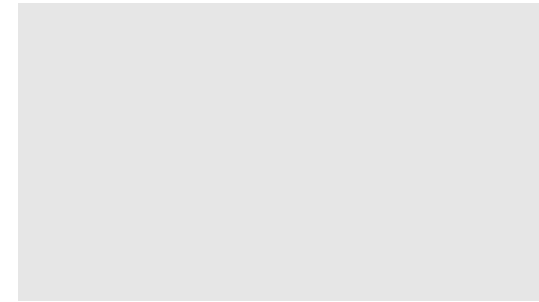
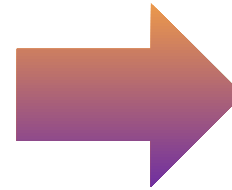


IBFM



matRadiomics is a freeware that allows the user to carry out the whole radiomics framework:

- 
- 1 import medical images
 - 2 segmentation
 - 3 feature extraction
 - 4 feature selection
 - 5 model building
 - 6 prediction.



La nostra risposta a LLM (Large Language Model)...



Specifiche tecniche

Processore

Processore Intel® Core™ Ultra 9 285K (24 core, 76 MB di cache totale, da 3,7 GHz a 5,7 GHz)

Sistema operativo

(Dell Technologies consiglia Windows 11 Pro per le aziende)
Windows 11 Pro

Scheda grafica

NVIDIA® GeForce RTX™ 5090 da 32 GB GDDR7

Memorie

64 GB di DDR5 (2 da 32 GB - verde) fino a 6.400 MT/s

Storage

SSD M.2 2280 da 2 TB con DRAM Gen4x4 TLC SED

Microsoft Office

Attivi Microsoft 365 per una prova gratuita di 30 giorni

Gestione dei sistemi software

Alienware Area-51 AAT2250

Lingue del sistema operativo

Inglese, olandese, francese, tedesco, italiano

Servizi di supporto

Alienware Care con l'assistenza in loco dopo la diagnosi da remoto

Garanzia di base

Basic Hardware Service con supporto on-site dopo la

Tastiera

Dell Pro 3 Wired Keyboard - KB216 - Italian (QWERTY) - Black

Tastiera

Nessuna tastiera selezionata

Topi

Mouse con cavo Dell Pro 3, MS116, nero

Mouse

Nessun mouse selezionato

Porte

Porte superiori

1 ingresso microfono
1 uscita linea
2 porte USB 3.2 Gen1 Type-A (5 Gb/s)
2 porte USB 3.2 Gen 2 Type-C (10 Gb/s) con tecnologia PowerShare

Porte posteriori

1 uscita digitale SPDIF (TOSLINK)
1 uscita linea
1 ingresso linea
2 porte Thunderbolt 4
2 porte USB 3.2 Gen 2 Type-C (10 Gb/s)
1 USB 3.2 Gen 1 Type-A (5 Gb/s)
3 x USB 2.0
2 porte USB 2.0 con tecnologia Smart Power

Slot

Specifiche PCIe di espansione M.2:
Slot 1 = fino a Gen5
Slot 2 = fino a Gen4
Slot 3 = fino a Gen4
1 slot per cavo di sicurezza Kensington

Dimensioni e peso

Altezza (massima): 569,00 mm (22,40")
Larghezza (massima): 231,60 mm (9,118")
Lunghezza (massima): 610,50 mm (24,04")
Peso massimo: 34,50 kg (76,10 lb)

Chassis

CPU da 240 mm, pannello laterale trasparente con raffreddamento a liquido
CPU da 360 mm, pannello laterale trasparente con raffreddamento a liquido

Senza fili

Wi-Fi 7 Intel® Killer BE1750 (2x2 320 Hz) MIMO 802.11be, LAN wireless e Bluetooth 5.4

Cavo di alimentazione

Nessun cavo di alimentazione

Cavo di alimentazione

Cavo di alimentazione, C13 a CEI 23-50, 1,8 m, 250 V, A, ITALIA

Case study: the MIRAGE project

MIRAGE — MicroRNA-targeted imaging for monitoring and prognostic stratification in nEuroendocrine tumors

PNRR-POC project 2023-12378163 · CNR-IBSBC (OU3) as partner for probe development, radiomics and in vivo testing

The rationale

A signature of 3 c-miRNAs (hsa-miR-5096, hsa-let-7i-3p, hsa-miR-4311) is associated with 18F-FDG PET/CT positivity in PNETs ($p < 0.005$).

The role of radiomics

matRadiomics extracts features from PET/CT to correlate them with miRNA expression, metabolism and SSTR2 expression.

The clinical goal

Integrate the molecular signature and radiomics features to improve diagnostic accuracy, prognosis and personalized care of NETs.

Ferrara Cohort

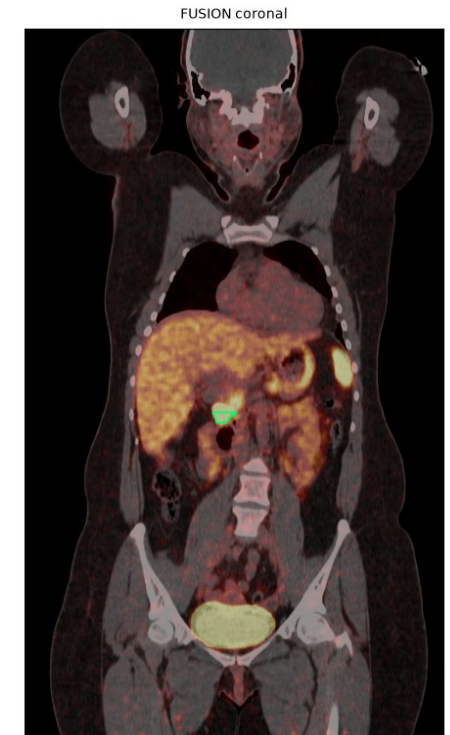
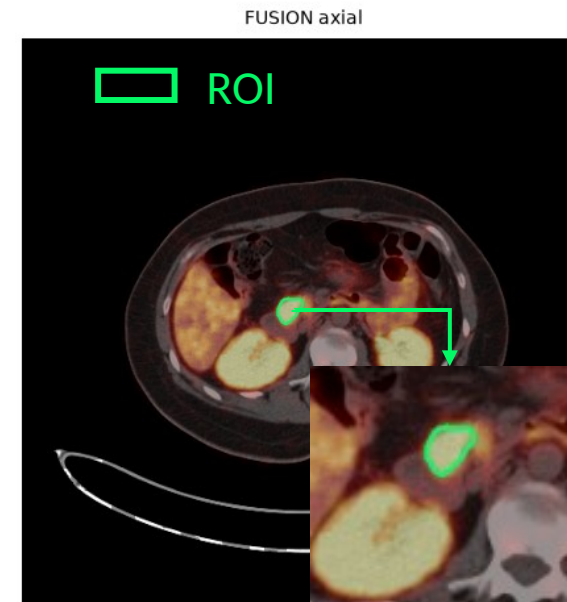
14 Patients

68Gallium-DOTATOC PET & Diagnostic CT

Messina Cohort

Pending Transfer

Independent multicenter validation set



Current Available Endpoint

Primary vs. Metastasis

Task: Stratification and phenotypic separation between primary neuroendocrine lesions (n = 10) and metastatic disease sites (n = 4) using standardized multimodal radiomics.

Pipeline 1

1. PREPROCESSING

Standardization

- **PET Conversion:** Radioactive decay & SUVbw calibration [g/ml].
- **CT Calibration:** Hounsfield Units with dedicated soft-tissue windowing.
- **Isotropic Resampling:** IBSI-standard 3D spline interpolation.
- **Discretization:** Fixed bin width to preserve absolute physical units.

2. DELINEATION

3D Dual VOI

- **Volume of Interest:** Manual expert 3D delineation across axial, coronal, and sagittal planes.
- **Centroid Alignment:** Lesion co-localization verified across CT, PET, and fused datasets.

3. EXTRACTION

matRadiomics Core

- **Framework:** PyRadiomics engine orchestrated inside matRadiomics freeware.
- **1,881 Features / Modality:** Parallel identical computation on CT and PET.
- **3,762 Total Features:** Full 26-connectivity 3D adjacency matrices.

Pipeline 2

9 Filter Domains (Multi-Frequency Space)

1. **Original:** Native unfiltered baseline volume.
2. **3D Wavelet (8 sub-bands):** Directional decomposition (LLL, LLH, LHL, LHH, HLL, HLH, HHL, HHH).
3. **LoG (Laplacian of Gaussian):** Progressive spatial gradients ($\sigma = 1.0, 2.0, 3.0, 4.0, 5.0$ mm).
4. **LBP (Local Binary Patterns):** Micro-contrast patterns on 2D slices and 3D blocks.

Mathematical Feature Classes

- **3D Morphology (Shape):** Volume, surface, sphericity, elongation, compactness.
- **First Order:** Mean, std dev, kurtosis, skewness, entropy, interquartile range.
- **Second Order (GLCM):** Contrast, dissimilarity, correlation, joint probability.
- **Higher Order:** GLRLM (run-length), GLSZM (size zone), GLDM, and NGTDM matrices.

Statistical Separation: Classical variables

Clinical Parameter	Metastasis (n=4)	Primary (n=10)	Cliff's δ	Exact p-value
Lesion Volume (ml)	1.74	1.89	+0.05	0.945
Lesion SUVmax	28.87	22.44	+0.15	0.733
Whole-Body SUVmax	94.00	79.01	+0.20	0.635
Total Voxel Count	1,738	1,885	+0.05	0.945

Standard quantitative parameters (SUVmax and Volume) exhibit completely overlapping distributions between primary tumors and metastases ($\delta \leq 0.20$; $p \geq 0.635$). → Direct clinical necessity to investigate intratumoral spatial heterogeneity using advanced texture radiomics.

Statistical Separation: Radiomics variables

Biomarker / Feature	Primary (n=10) Median [IQR]	Metastasis (n=4) Median [IQR]	Cliff's δ	Exact p
SUV max (lesion)	22.44 [9.48 – 47.18]	28.87 [14.90 – 35.36]	+0.15	0.733
Lesion Volume (ml)	1.89 [0.39 – 3.62]	1.74 [0.66 – 6.83]	+0.05	0.945
PET lbp-2D InterquartileRange *	1.00 [1.00 – 1.00]	0.00 [0.00 – 0.50]	-0.75	0.011 *
PET wavelet-LHL glcm Imc1	-0.32 [-0.34 – -0.31]	-0.39 [-0.41 – -0.36]	-0.80	0.024
CT LoG ($\sigma=1.0\text{mm}$) Mean	-2.28 [-2.89 – -1.29]	+0.09 [0.08 – 5.15]	+1.00	0.002
CT LoG ($\sigma=2.0\text{mm}$) Mean	-7.61 [-11.15 – -4.80]	+0.44 [-0.12 – 15.66]	+1.00	0.002

Volume and SUVmax display identical distributions between primary lesions and metastases ($\delta \leq 0.15$; $p \geq 0.73$). Local contrast patterns (LBP) and LoG spatial filters demonstrate complete separation, totally independent of lesion volume.

Machine learning and best features

PET MODEL EVALUATION

Best Trend

0.650

Leave-One-Out (LOO) AUC

- Balanced Accuracy: 52.5% (Brier: 0.230)
 - Permutation p: 0.2695 (500 runs)
- Null mean AUC: 0.488 (95th percentile = 0.876)
- 1 feature selected per cross-validation fold

1 Feature Survived maxT

PET lbp-2D InterquartileRange (p = 0.0110)

Cliff's $\delta = -0.75$ · maxT FWER = 0.031 (Robust at 5% FWER threshold).

High-Frequency Spatial Texture

PET wavelet-LHL glcm Imc1 / MCC (p = 0.0240)

Cliff's $\delta = \pm 0.80$ · Directional sub-band relationship.

Size Independence

PET wavelet-HHL glcm MaxProbability (p = 0.0240)

Cliff's $\delta = -0.80$ · Only 2 of 30 top candidates correlated with lesion volume.