MRO . ART
MODERN RADIATION ONCOLOGY
35° RESIDENTIAL COURSE

Seeing Lung Cancer Differently: AI and Imaging Innovation from Diagnosis to Follow-Up

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Rome, Italy, 27 October 2025

ARC
Advanced Radiology Center

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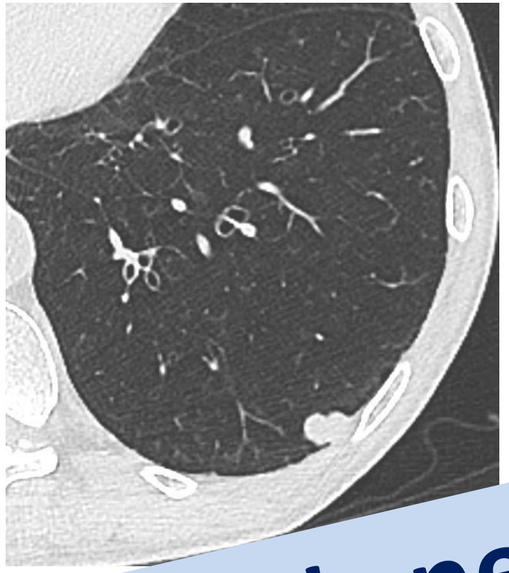
Università Cattolica del Sacro Cuore

C-ART
Advanced Radiation Therapy

Lung Cancer

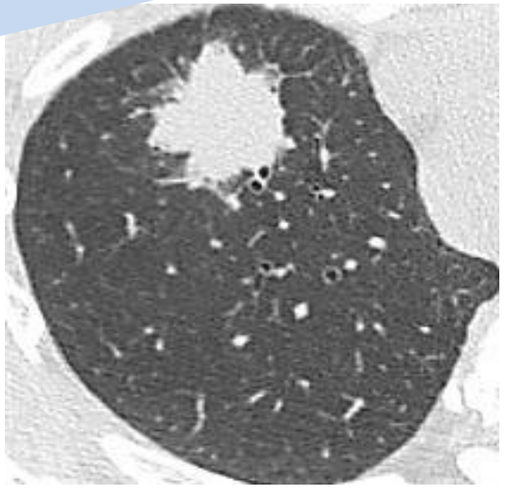
Lung Nodule



- **Detection**
- **Characterisation**
  (benign vs malignant)

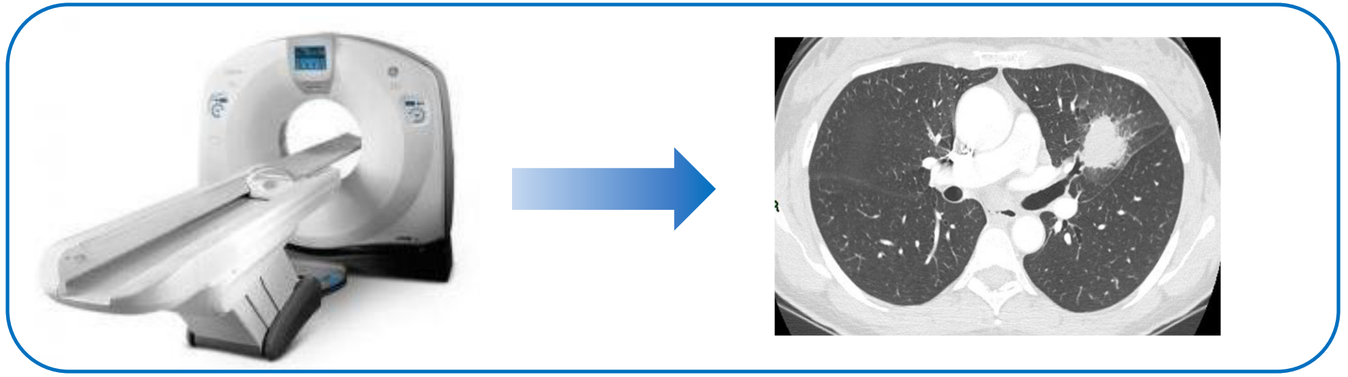
What's new?

Lung Cancer



- **Histology**
- **Staging**
- **Treatment monitoring**
  (treatment response, toxicity…)

What's new ?



How to generate imaging

What to extract from imaging

IMAGING INNOVATION

ARTIFICIAL INTELLIGENCE

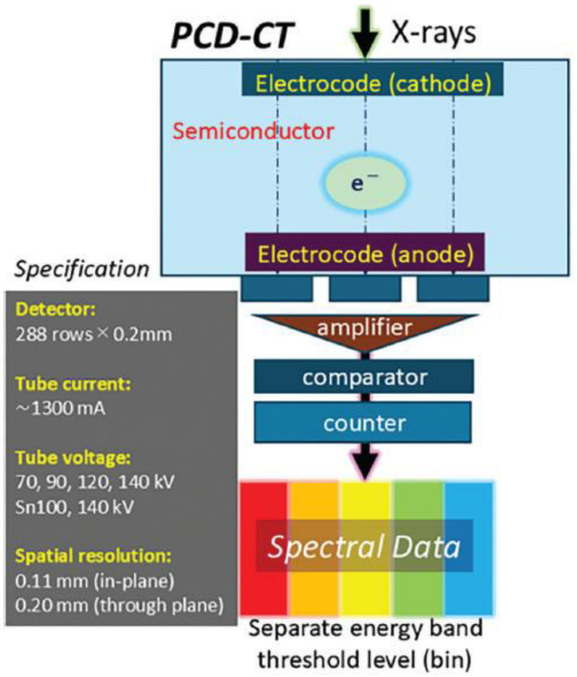
Imaging innovation & Lung nodule/cancer

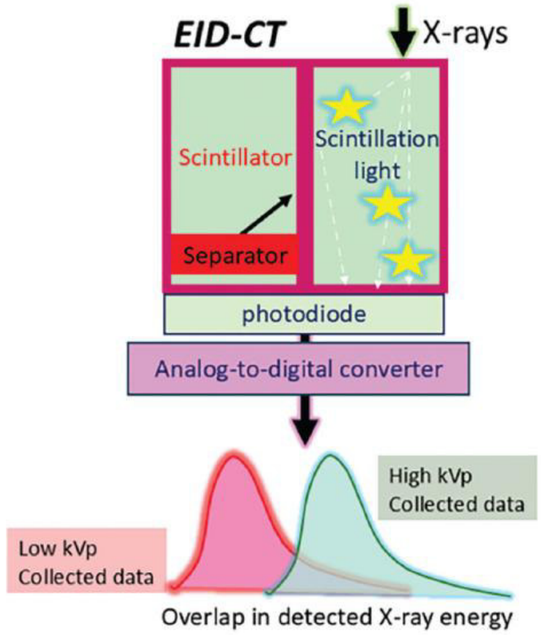
Photon-Counting – CT

«…uses new energy-resolving x-ray detectors, with mechanisms that differ substantially from those of conventional energy-integrating detectors. Photon-counting CT detectors count the number of incoming photons and measure photon energy…»

- ↑ **spatial resolution** (ultra-HR, 0.11 mm)
- ↓ **radiation exposure** (up to 40%)
- ↑ **image quality**
- ↑ **contrast-to-noise ratio**
- ↓ **contrast medium**
- ↑ **spectral resolution**

(multienergy imaging & new quantitative data)





Precise X-rays analysis

Yanagawa M - Diagn Inter Radiology 2025. DOI: 10.4274/dir.2025.253550

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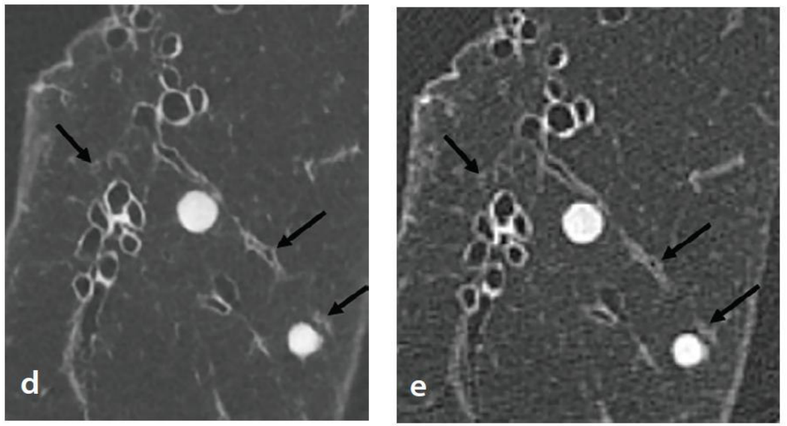


&

AI-based reconstruction algorithms
(super-resolution techniques)

More precise tumor detection and characterization
& potential benefits in computational approaches (AI)

Yanagawa M - Diagn Inter Radiology 2025. DOI: 10.4274/dir.2025.253550

Imaging innovation & Lung nodule/cancer

Photon-Counting – CT

PCD-CT vs EID-CT

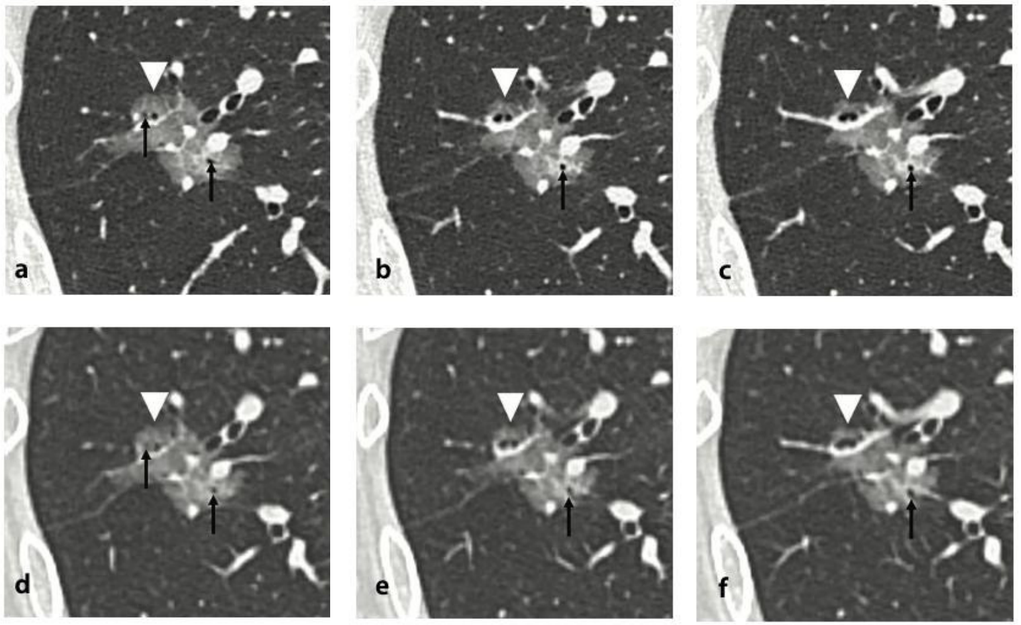
Lung Cancer Screening Using Clinical Photon-Counting Detector Computed Tomography and Energy-Integrating-Detector Computed Tomography: A Prospective Patient Study

- **mean CTDI**vol: 0.61±0.21 vs 0.73±0.22 (p< 0.001)
- **image noise:** 74.4±10.5 vs 80.1±8.6 HU (p=0.048)
- **diagnostic image quality:**
  - ✓ sharpness
  - ✓ lung nodule boundaries
  - ✓ emphysema

Significant differences for all comparative rankings (PCD-CT favored)

PCD-CT

EID-CT



*Inoue A – J Comput Assist Tomogr 2023;47: 229–235

Yanagawa M - Diagn Inter Radiology 2025. DOI: 10.4274/dir.2025.253550

Imaging innovation & Lung nodule/cancer

Photon-Counting – CT

X-ray dose vs low-dose PCD-CT

- **mean CTDI**vol: 0.11±0.03 vs 0.65±0.15 ($p < 0.001$)
- **SENSITIVITY** of semiautomated method for nodule detection was high (0.94)
- **Nodule Volumetry** by semiautomated method was similar in x-ray dose scans and low-dose scans
- **Lung-RADS nodule classification** is accurate on x-ray dose scans and similar to low dose scans

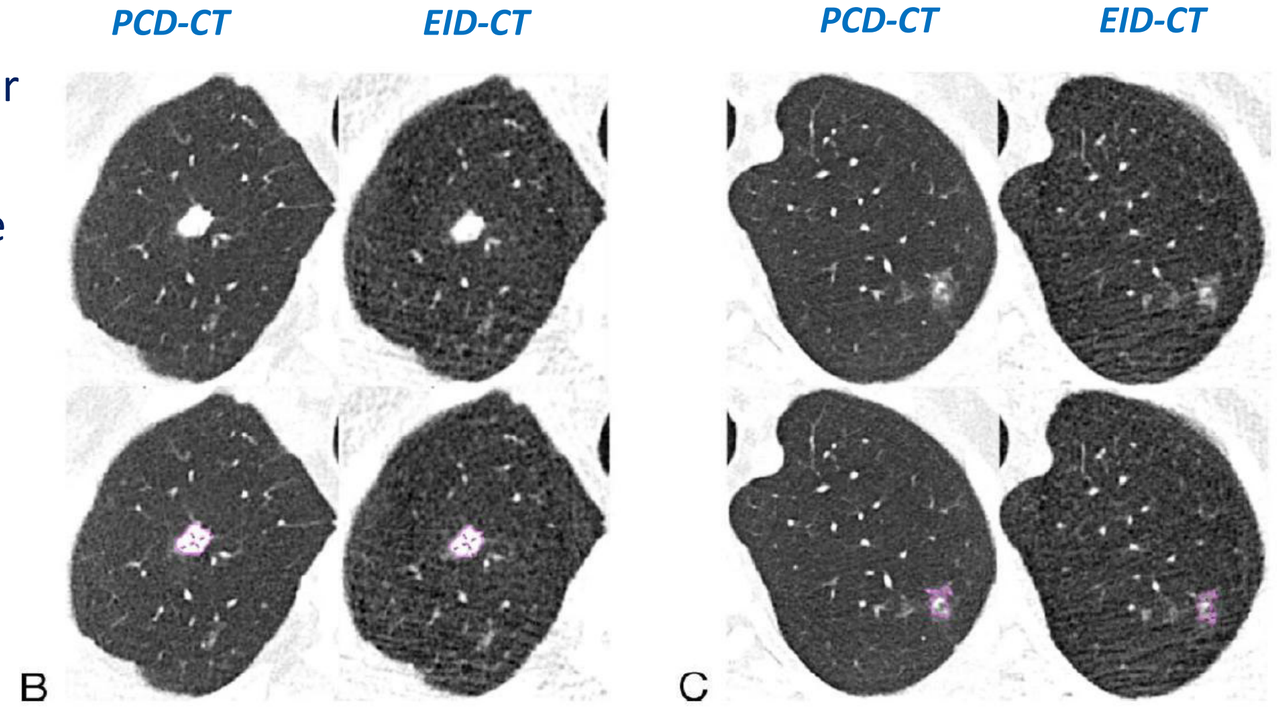
X-ray dose PCD-CT is promising:

- for nodule overall assessment in LCS
- to reduce the risks of cumulative radiation exposure

The Effect of X-ray Dose Photon-Counting Detector Computed Tomography on Nodule Properties in a Lung Cancer Screening Cohort

A Prospective Study

Bjarne Kerber, MD, Falko Ensle, MD, Jonas Kroschke, MD, Cecilia Strappa, MD, Ricarda Stolzmann-Hinzpeter, MD, Christian Blüthgen, MD, Marc Marty, MD, Anna Rita Larici, MD, Thomas Frauenfelder, MD, and Lisa Jungblut, MD



Kerber B et al – Invest Radiol 2025. doi: 10.1097/RLI.0000000000001174

Imaging innovation & Lung nodule/cancer

Photon-Counting – CT

Table 1. Thoracic oncology tasks and photon-counting detector computed tomography (PCD-CT) advantages: evidence map

Clinical task	Specific question	Typical comparator	Study type (examples)	Primary metrics (examples)	Reported signal	Clinical implication	References
Tumor morphology and margins (solid tumor evaluation)	Does PCD-CT provide clearer visualization of tumor margins and fine morphological features (e.g., spiculation, lobulation) compared with conventional CT?	High-resolution EID-CT (ultra-thin slices with iterative recon)	*Ex vivo* cadaver lung comparisons; prospective clinical studies with artificial intelligence super-resolution reconstruction	Spatial resolution (achieved voxel size); minimum detectable lesion size; clarity of edge features (spiculation, air bronchograms); reader confidence scores	↑ (Improved)	Enhanced delineation of tumor extent and characteristics, improving lesion characterization and aiding precise surgical or radiotherapy planning	9,20
Lymph node staging (mediastinal metastasis detection)	Can PCD-CT spectral imaging improve identification of metastatic lymph nodes in thoracic malignancies compared with standard CT or dual-energy CT?	Contrast-enhanced EID-CT or dual-energy CT (with iodine mapping)	Retrospective clinical spectral CT studies (with surgical pathology as reference); phantom iodine-detection experiments	Iodine concentration in nodes (correlation with malignancy); virtual monoenergetic imaging clarity; minimum detectable iodine level (phantom)	↑ (Improved)	Potential for more accurate non-invasive nodal staging – improved detection of nodal metastases due to superior contrast and spectral sensitivity, possibly reducing need for invasive sampling	63,64
Treatment response assessment (sherapy monitoring)	Does PCD-CT improve the evaluation of tumor response to therapy (e.g., changes in size or enhancement) compared with conventional CT?	Standard contrast-enhanced CT (EID-CT or latest dual-source CT)	Preliminary clinical comparisons in oncology patients (PCD-CT vs. dual-source CT)	Tumor-to-lung contrast ratio; lesion conspicuity on follow-up; image noise and SNR; dose per scan	↑ (Improved)	Clearer visualization of residual tumor and subtle changes in enhancement or size, facilitating more confident assessment of treatment efficacy while minimizing radiation and contrast burden	43

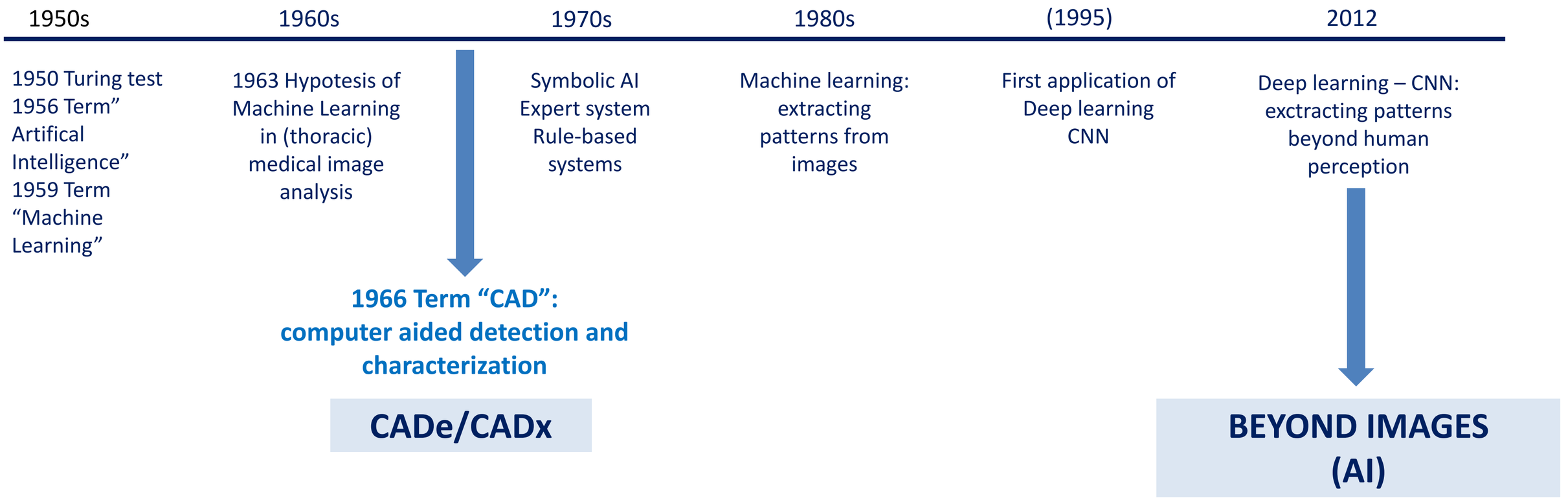
PCD-CT will be a powerful tool:

- tumor characterization
- treatment planning
- lymph node evaluation
- residual tumor after treatment

Yanagawa M - Diagn Inter Radiology 2025

AI & Lung Cancer

“Artificial intelligence (AI) is the branch of computer science devoted to creating systems to perform tasks that ordinarily require human intelligence ... learning and problem solving”



Chartrand G - Radiographics. 2017 Nov-Dec ; 37(7):2113-2131
ESR - Insight Imaging 2019. Apr 4; 10(1):44.
van Ginneken B - Radiol Phys Technol 2017 Mar; 10 (1):23–32.

Iglesias L - Insight Imaging 2021. Aug 12; 12(1):117.
Ather S - Clinical Radiology 2020 Jan; 75(1): 13-19.
Lambin P - Eur J Cancer 2012 Mar; 48(4):441–6.

AI & Lung Cancer

AI to augment imaging technology → **CT**, **MRI**, **PET-CT**

CAD →
- Detec Characterization

RADIOMICS →
- Genera gh-dimensional quantitative data
- Suppo gnosis and patient management at any point of imagin kflow
- Can be bined with other patient characteristics to produce power pport tools

CNNs →
- A subc DL in which images are input into the predictive algorithm directly

These data can be combined with other factors such as gene expressions/mutations and molecular signatures to refine prognostication

AI & Lung nodule

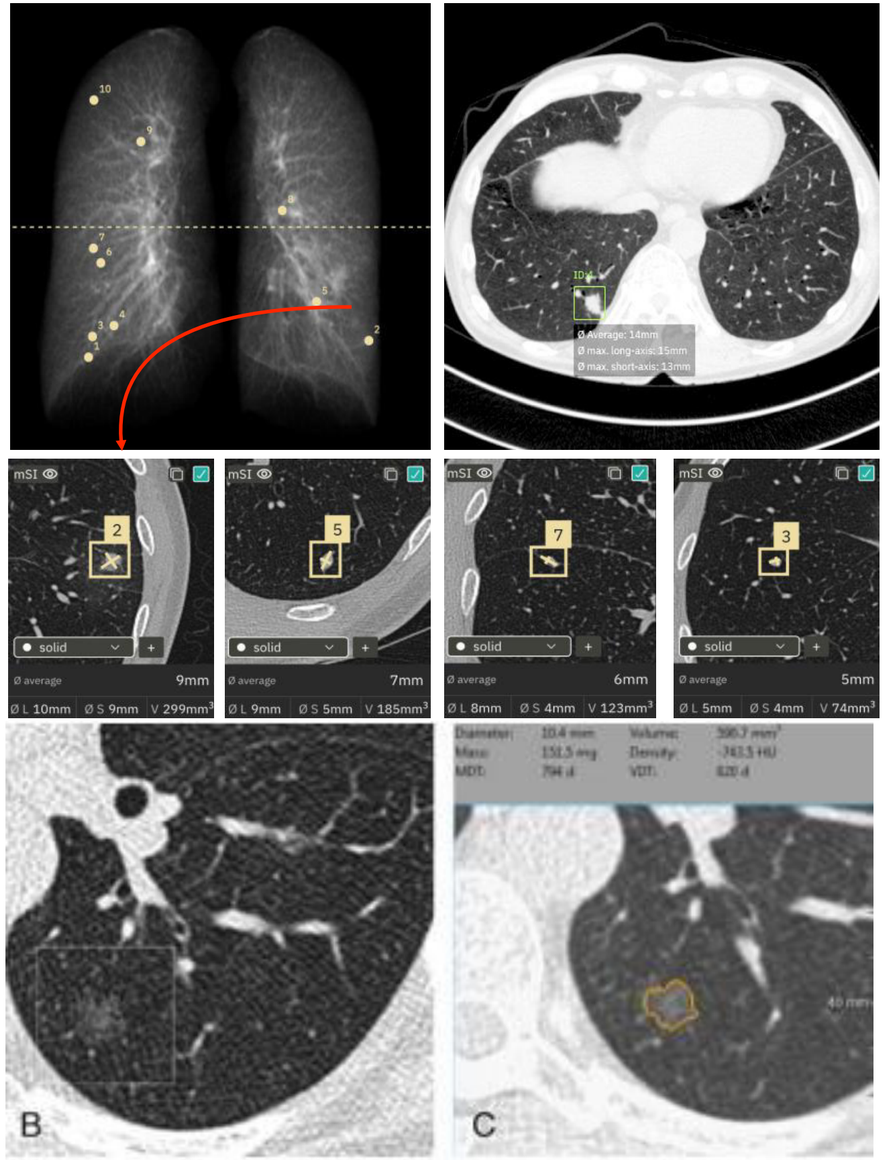
CADe (computer-aided detection)

AI-based nodule detection (DL + large annotated database LIDC):

- ***SENSITIVITY***: 98.1% with 2.2 FP per scan*
- reduce reading time
- high performance in all nodule types (+++small nodules)
- comparable or slightly inferior to human readers
- risk of FN (pulm.mass/mediast.lesions)

AI Algorithms approved as concurrent or ***second reader***

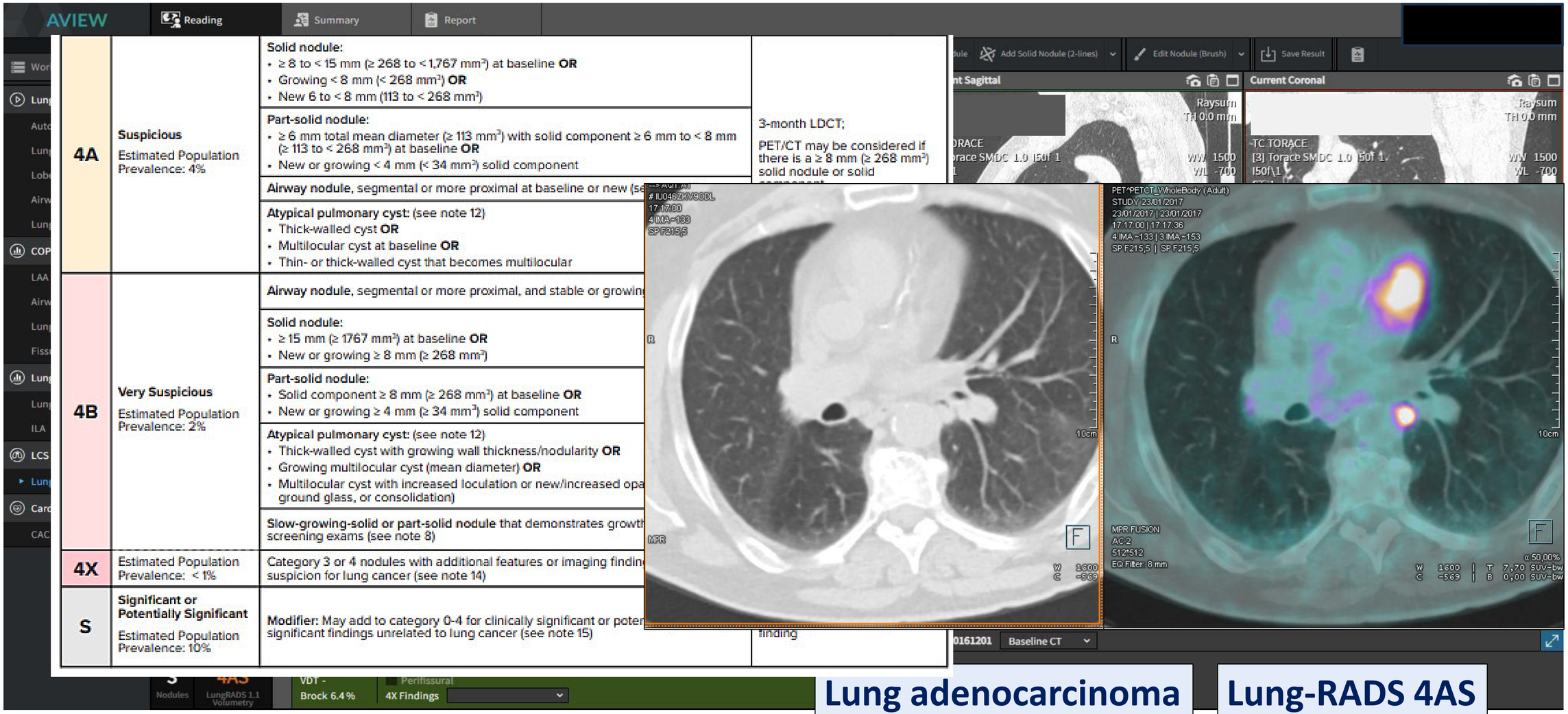
- **CAD** potentially improves variability in LDCT interpretation across radiologists with different levels of expertise**



* Massod A - IEEE Trans Ind Inf. 2020
** Hwang EJ - Eur Radiol 2021
Silva M - Investigative Radiology 2018
Schreuder A - Trans. Lung Canc Res. 2021

AI & Lung nodule

CADx (computer-aided diagnosis)/categorization



Lung adenocarcinoma
pT1bN0M0, Stage IA2

Lung-RADS 4AS

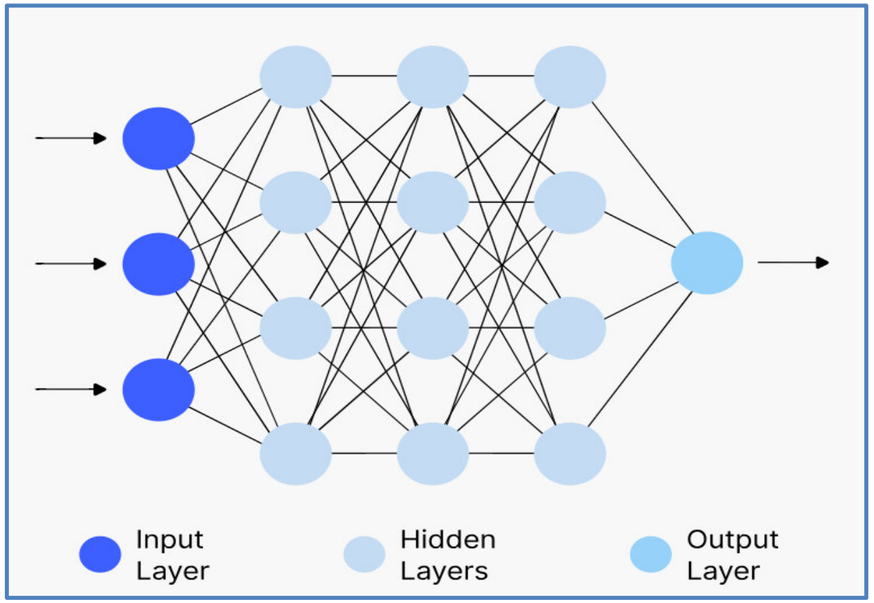
AI & Lung nodule

CADx (computer-aided diagnosis)/characterization

CNN model tested to predict lung nodule malignancy

- **Low-dose CT scans of 6716 individuals from NLST dataset**
- **Independent dataset of 1139 individuals**
  - AUC 0.94
  - AUC 0.95

vs 6 radiologists



➢ If prior CT scan was not available the model outperformed all radiologists:

↓ 11% FP
↓ 5% FN

➢ If prior CT scan was available the performance was comparable to that of the radiologists

Ardila D - Nat. Med. 2019; 25: 954–961

AI & Lung cancer

Radiomics

PubMed®

radiomics and lung cancer

Search

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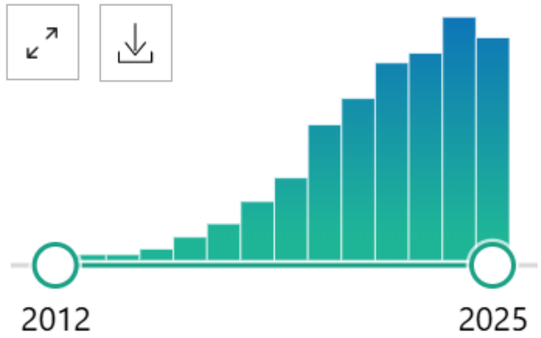
MY CUSTOM FILTERS

2,299 results

Page 1 of 230

RESULTS BY YEAR



1

Cite

Radiomics and artificial intelligence for precision medicine in **lung cancer** treatment.

Chen M, Copley SJ, Viola P, Lu H, Aboagye EO.

Semin Cancer Biol. 2023 Aug;93:97-113. doi: 10.1016/j.semcancer.2023.05.004. Epub 2023 May 19.

PMID: 37211292 Free article. Review.

Lung cancer is the leading cause of **cancer**-related deaths worldwide. It exhibits, at the mesoscopic scale, phenotypic characteristics that are generally indiscernible to the human eye but can be captured non-invasively on medical imaging as **radiomic** fe ...

AI & Lung cancer

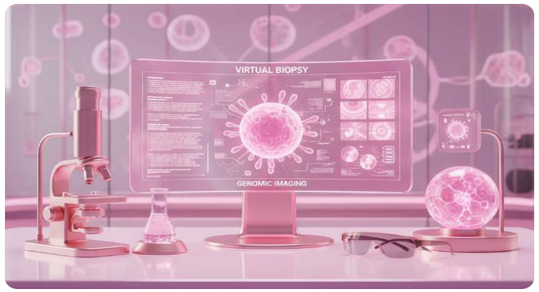
Radiomics

Benign vs Malignant Nodules

One of the first and most crucial applications in clinical practice, particularly useful in screening settings for early detection. Radiomics provides critical guidance for confident nodule management decisions.

Histological Subtyping

Enables differentiation of adenocarcinomas (ACs) versus squamous cell carcinomas (SCC), and assesses invasiveness characteristics of adenocarcinomas, providing essential support for comprehensive cancer treatment planning.



Radiogenomics

Functions as a **"virtual biopsy"**, offering a comprehensive, non-invasive assessment of tumoral heterogeneity by correlating imaging features with genomic information, reducing the need for invasive procedures.

Prognosis/Response to Therapy

Radiomics guides optimal therapy selection based on objective tumor characteristics, enables accurate prediction of tumoral response to treatment, and facilitates real-time therapy adaptation for improved patient outcomes.

❖ Clinical Impact

Radiomics transforms thoracic oncology by providing <u>non-invasive, comprehensive tumor analysis</u> that can guide treatment decisions and improves patient outcomes.

❖ Future Applications

Continued advancement in imaging biomarkers promises even more <u>precise cancer characterization</u> and <u>personalized treatment approaches</u>.

Courtesy of G. Milanese

Boubnovski Martell M - Clinical Radiology 2025
Balbi M - JTI 2024
Khorrami M - Cancer Immun Res 2019

AI & Lung cancer

Staging (T N M)

- *Invasive vs. Indolent adenoCa SSN*
  sistematic review of 28 studies, CT, traditional/DL
  AUC: 0.78-0.97 test set /0.77-0.98 validation set
  Shi L - Eur J Radiol 2021
- *Spread through air spaces (STAS)*
  non-sistematic review, CT, traditional/DL
  AUC: 0.69-0.99
  Wang J - Transl Cancer Res 2023
- *T1-T2 vs T3-T4 classification*
  475 pts; PET/CT, CNN
  Accuracy 89%
  Kirienko M - Contrast Media Mol. Imaging 2018

- *LFN mts*
  sistematic review/meta-analysis, 6 studies, CT/PET-CT, traditional/DL
  pooled AUROC 0.74
  Zheng X - Front Public Health 2022
- *N2 prediction*
  CT, DL, 3,096 clinical stage I patients
  AUC 0.82
  Zhong Y - Radiology 2022

- *Distant metastases*
  689 pts, CT, DL
  AUC 86.44 testing set
  Mu J - Front Med 2023

Contributes to choosing the most suitable treatment strategy & follow-up schedule

AI & Lung cancer

Clinical Outcome Prediction

❖ Therapy response, Disease Recurrence or Progression

- ***Radiol./pathol. response for any tp (except IT) for any stage NSCLC***
  review, 12 studies/9 Radiomics, baseline/early treatment, CT/PET-CT, traditional
  AUC 0.62-0.86; OR 1.093-1.107
  Chetan M - Eur Radiol 2021

- ***Immunotherapy response***
  systematic review/meta-analysis, 7 studies/4 ma, CT/PET-TC, traditional
  pooled OR 14.99
  Chen Q - Eur J Nucl Med Mol Imaging 2021

- ***Recurrence in early stage NSCLC***
  narrative review, 13 studies, CT/PET-TC, traditional, tumor/peritumor,
  «encouraging results, any comparison and aggregation [...] complicated by variabilities»
  Libling WA - Transl Lung Cancer Res 2023

Stratification of Patients for Treatment planning

AI & Lung cancer

Clinical Outcome Prediction

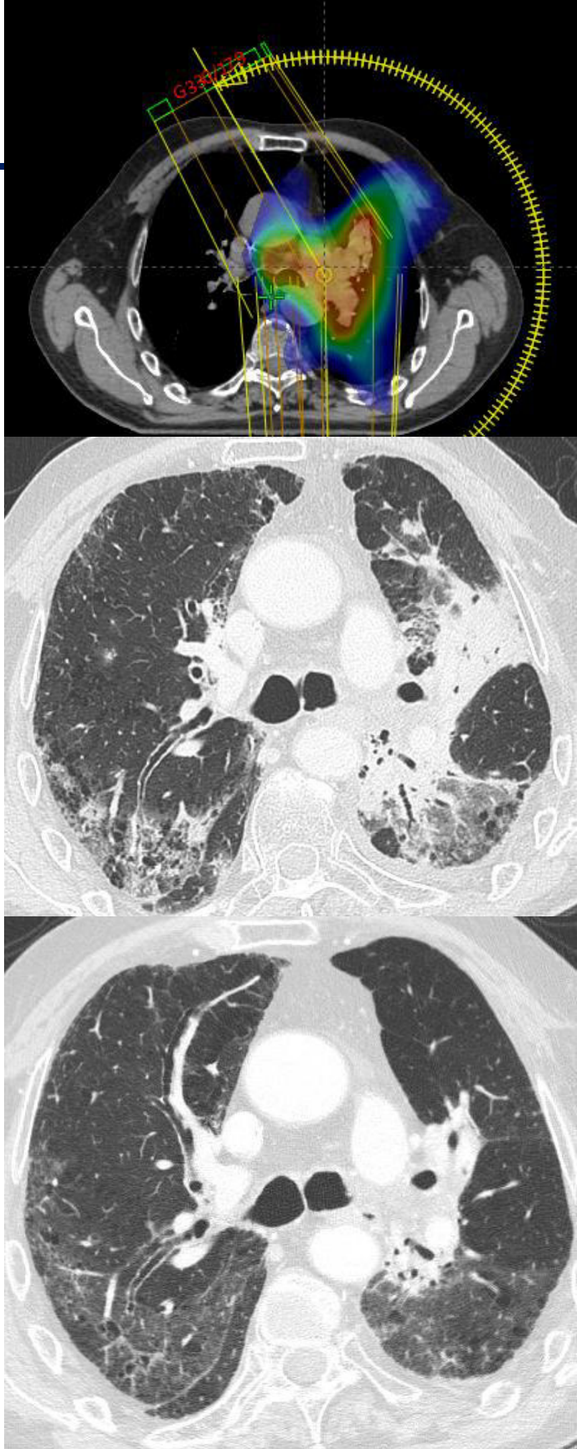
❖ Adverse Events/Toxicity

- **Pneumonitis after Radiotherapy or Immunotherapy**
  systematic review/meta-analysis, 56 studies (12,803 pts.), ML-based model

  ➢ **Prediction of Radiation Pneumonitis**: pooled c-index 0.87 (TS), 0.82 (VS)
  Radiomics + dosiomics models: c-index 0.92 (TS), 0.90 (VS)

  ➢ **Prediction of Checkpoint Inhibitor Pneumonitis**: pooled c-index 0.85 (TS), 0.84 (VS)
  Radiomics + clinical characteristics: c-index 0.88 (TS), 0.86 (VS)

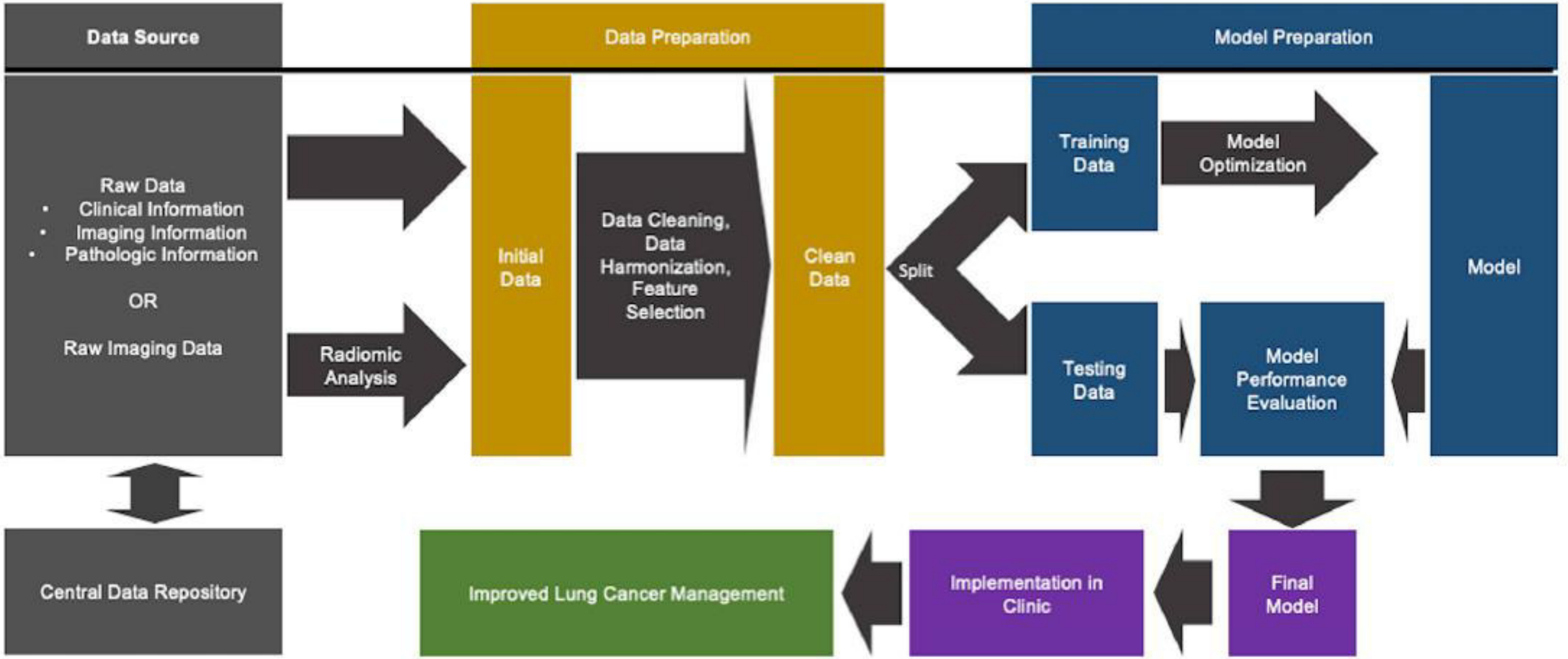
  ➢ **Distinction Radiation Pneumonitis (RP)/ Checkpoint Inhibitor Pneumonitis (CIP)**
  only 2 studies
  AUC for RP 0.95; for CIP 0.88



Wang S - Sci Rep 2025;15(1):20961

AI & Lung Cancer

- **Simplified scheme of workflow for implementation of AI in lung cancer clinic on the basis of artificial intelligence best practices**

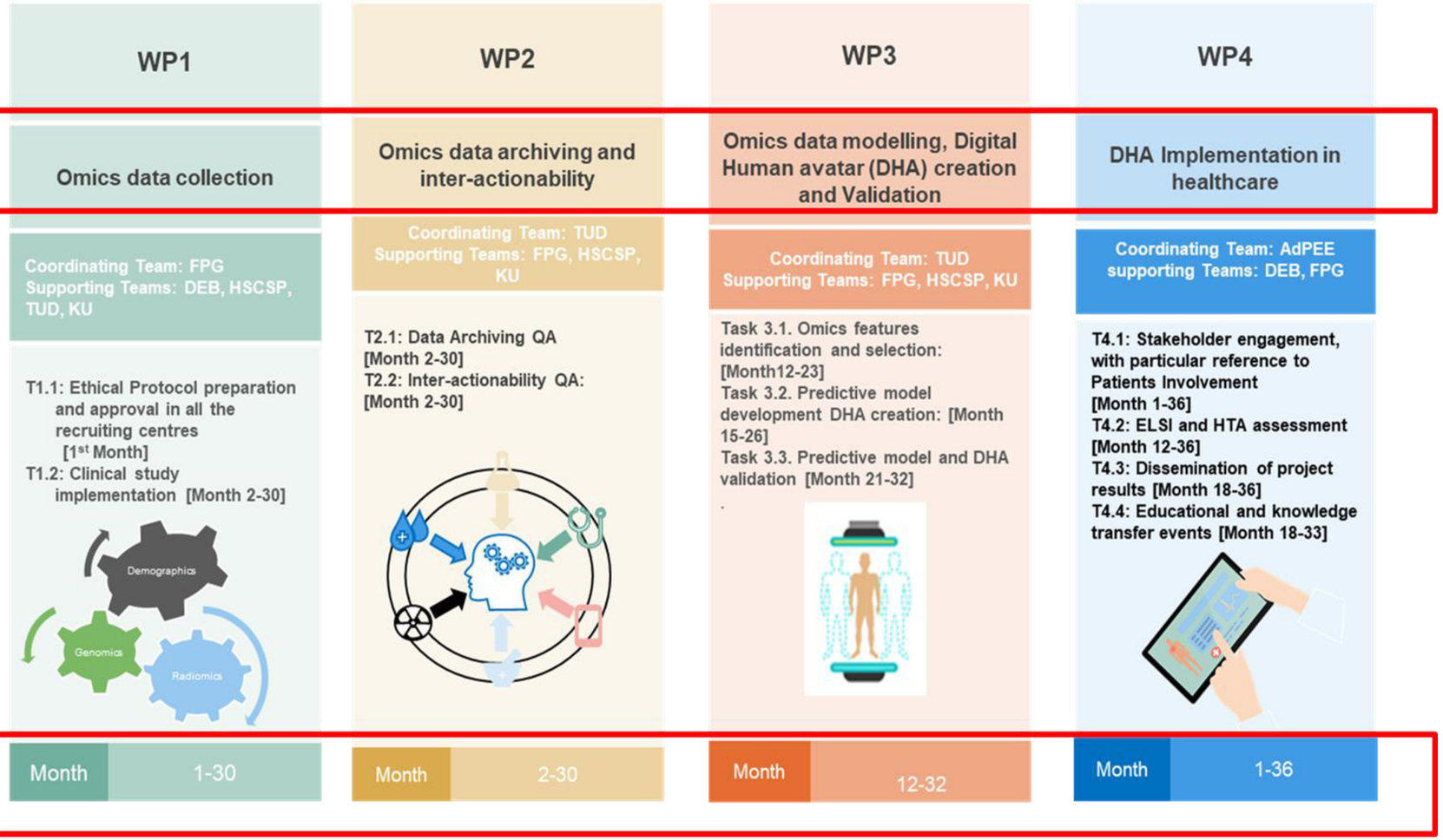


Ladbury C - Cell Reports Medicine 2023

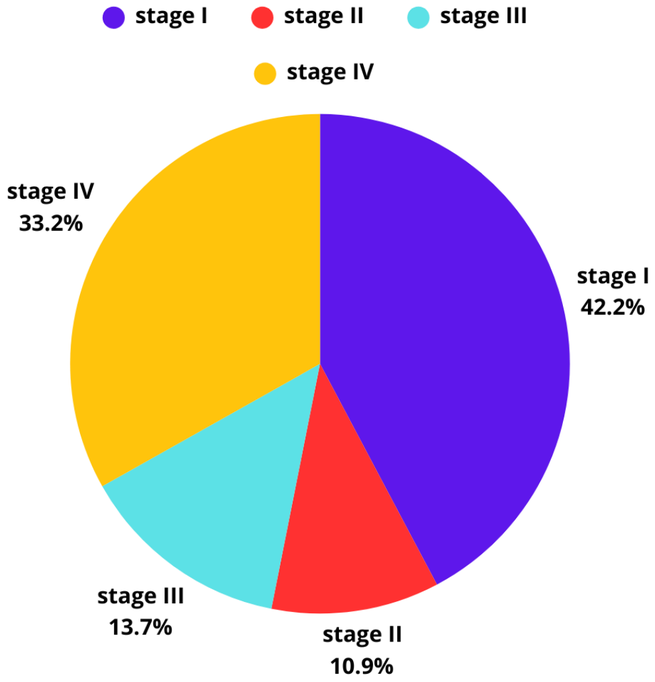
AI & Lung cancer

LANTERN Project: Lung cANcer multi-omics avaTars for intEgrated pRecision mediciNe[1,2]

- The main objective is to revolutionize decision-making on lung cancer by using advanced predictive digital platforms.



- **561 pts with NSCLC**
- **5 European cancer centers**



[1]***Courtesy of F. Lococo,*** *UOC Thoracic Surgery*
[2]***Courtesy of L. Boldrini,*** *UOC Oncologic Radiotherapy, Knowledge Based Oncology Lab.*
Fondazione Policlinico Universitario A. Gemelli IRCCS
Università Cattolica del Sacro Cuore, Roma

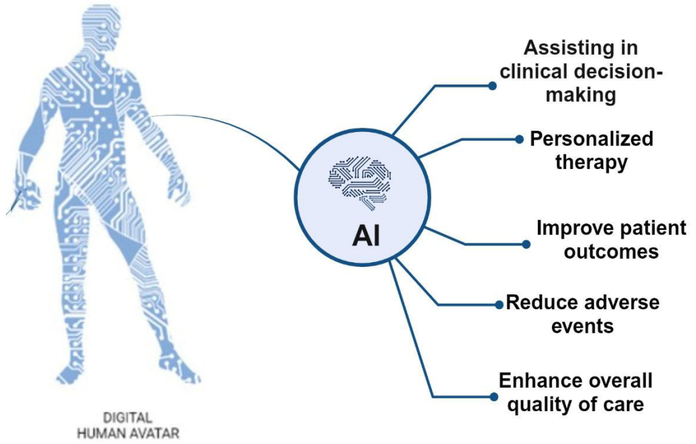
AI & Lung cancer

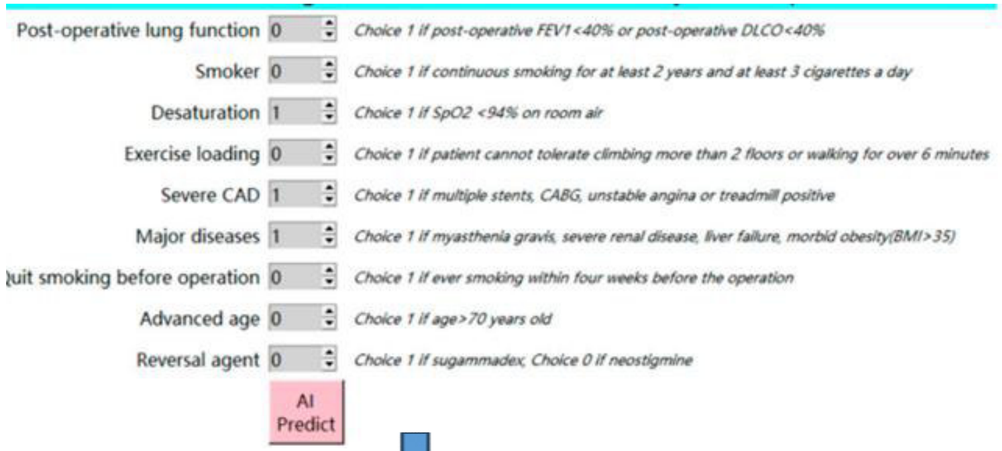
LANTERN Project: Lung cANcer multi-omics avaTars for intEgrated pRecision mediciNe[1,2]

GOAL: application DHA in Clinical Practice

Clinical data

Input





- *56 y-o female*
- *Mucinous adenocarcinoma*
- *4.2 cm (RUL)*
- *SUVmax: 7.3*
- *Radiomics features…..*
- *VATS Lobectomy*
- *pStage Ib (10 LFN removed)*
- *NGS: Mutation NTRACK + MDM4, PDL-1 6%*

Output

- *Overall Estimated Rate of Relapse: 48%*
- *Estimated Rate of Loco-regional Relapse: 5%*
- *Estimated Rate of Distant Relapse: 46%*
- *Estimated Rate of Brain Relapse: 46%*

[1]***Courtesy of F. Lococo,*** *UOC Thoracic Surgery*
[2]***Courtesy of L. Boldrini,*** *UOC Oncologic Radiotherapy, Knowledge Based Oncology Lab.*
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What’s new ?

IMAGING INNOVATION

Synergistic collaboration

ARTIFICIAL INTELLIGENCE

Paving the way for more precise and personalized oncology care

…but we need to build robust, accessible and validated models designed to improve pt. care

Acknowledgements

Alessandra Farchione
Giuseppe Cicchetti
Cecilia Strappa