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# Transforming Healthcare

AI in diagnostic imaging: why?

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# Artificial Intelligence in diagnostic imaging: why?



van Leeuwen KG, et al. How does artificial intelligence in radiology improve efficiency and health outcomes? Pediatr Radiol 52, 2087–2093 (2022).





3<sup>rd</sup> AI boom Computer performance Third AI boom is over 10 million times Reasoning by learning **Deep Learning** Second AI boom Inference by knowledge First AI boom Inference by search Start of CAD Winter research Winter U of Chicago Year 1960 2010 1980 AI-CAD 1998 Automated diagnosis/ Commercialization of CAD CAD research started

Fujita, H. Al-based computer-aided diagnosis (AI-CAD): the latest review to read first. Radiol Phys Technol 13, 6–19 (2020).

A

Expected Level of







Pesapane F et al. Artificial intelligence in medical imaging: threat or opportunity? Radiologists again at the forefront of innovation in medicine. Eur Radiol Exp 2, 35 (2018).





# Potential applications of Artificial Intelligence in diagnostic imaging



Bradshaw, T. J. et al. Nuclear Medicine and Artificial Intelligence: Best Practices for Algorithm Development. Journal of Nuclear Medicine 63, 500–510 (2022).





## Al applications for image quality restoration



Chaudhari, A. S. et al. Low-count whole-body PET with deep learning in a multicenter and externally validated study. npj Digital Medicine 2021 4:1 4, 1–11 (2021).





## Al applications for image quality restoration



Weyts, K. et al. Artificial intelligence-based PET denoising could allow a two-fold reduction in [18F]FDG PET acquisition time in digital PET/CT. Eur J Nucl Med Mol Imaging 49, 3750–3760 (2022).





## **Artificial Intelligence in lesion detection and diagnosis**

#### Detection

Detecting potential abnormalities within images on the basis of changes in intensities or the appearance of unusual patterns, with an emphasis on reducing false positives











Segmentation Defining the boundary extent of an abnormality for subsequent diagnosis and treatment planning

#### Diagnosis

Evaluating and classifying abnormalities such as benign vs malignant

#### Staging

Classifying abnormalities into multiple predefined categories such as the TNM classification of malignant tumours







## Computer-Aided Detection (CADe) and Diagnosis (CADx) systems

Detection and Diagnosis Results Type of Imaging Output by AI Algorithms Triage of positive films to top of **Right-side** radiology worklist pneumothorax **Chest Radiograph** Detection and D localization Left upper-lobe of abnormalities solid nodule Mass: 13 mm Characteristics: Solid Change: +20% **Chest CT Scan** Localization and quantification of Spiculated mass, abnormalities mid-right breast Mass: 4 cm<sup>2</sup> Characteristics: Spiculated solid mass Mammogram Microcalcifications present Architectural distortion present Likelihood of cancer: 7 in 10

Rajpurkar P. et al. The Current and Future State of AI Interpretation of Medical Images. The New England Journal of Medicine 388: 1981-1990 (2023)

# Detection: Computer-Aided Detection.









#### Al applications for segmentation



Decuyper, M., Maebe, J., van Holen, R. & Vandenberghe, S. Artificial intelligence with deep learning in nuclear medicine and radiology. EJNMMI Physics 2021 8:1 8, 1–46 (2021).





## Al applications for segmentation



Girum K.B. et al. 8F-FDG PET Maximum-Intensity Projections and Artificial Intelligence: A Win-Win Combination to Easily Measure Prognostic Biomarkers in DLBCL. Journal of Nuclear Medicine 63: 1925-1932 (2022)

#### eXplainable Artificial Intelligence in healthcare Management 2020-EU-IA-0098 Diagnosis: Machine Learning vs Deep Learning





# Diagnosis: Al applied to mammography for breast cancer screening





Yoon, J. H. & Kim, E. K. Deep Learning-Based Artificial Intelligence for Mammography. Korean J Radiol 22, 1225–1239 (2021).



#### Malignant





#### True positives

False negatives









#### **Diagnosis: AI applied to low-dose chest CT for lung cancer screening**



Ardila, D. et al. End-to-end lung cancer screening with three-dimensional deep learning on low-dose chest computed tomography. Nature Medicine 2019 25:6 25, 954–961 (2019).





# Staging: AI applied to [18F]FDG PET/CT in lymphoma



Weisman, A. J. et al. Convolutional neural networks for automated pet/ct detection of diseased lymph node burden in patients with lymphoma. Radiol Artif Intell 2, 1–2 (2020).







Weisman, A. J. et al. Convolutional neural networks for automated pet/ct detection of diseased lymph node burden in patients with lymphoma. Radiol Artif Intell 2, 1-2 (2020).



## eXplainable Artificial Intelligence in healthcare Management Non-suspicious Suspicious







Sibille, L. et al. 18F-FDG PET/CT uptake classification in lymphoma and lung cancer by using deep convolutional neural networks. Radiology 294, 445–452 (2020).



Change Detector Output



#### Monitoring: AI applied to serial MRI studies in brain tumours





Patriarche, J. W. & Erickson, B. J. Part 1. Automated change detection and characterization in serial MR studies of brain-tumor patients. J Digit Imaging 20, 203–222 (2007).







Zeleznik, R. et al. Deep convolutional neural networks to predict cardiovascular risk from computed tomography. Nature Communications 2021 12:1 12, 1–9 (2021).





# Outcome prediction: AI applied to [18F]FDG PET/CT in lymphoma



Girum K.B. et al. 8F-FDG PET Maximum-Intensity Projections and Artificial Intelligence: A Win-Win Combination to Easily Measure Prognostic Biomarkers in DLBCL. Journal of Nuclear Medicine 63: 1925-1932 (2022)





# AI applications in radiation oncology



Huynh, E. et al. Artificial intelligence in radiation oncology. Nature Reviews Clinical Oncology 2020 17:12 17, 771–781 (2020).





## Al applications in radiation oncology: outcome prediction



Tanaka, S. et al. A deep learning-based radiomics approach to predict head and neck tumor regression for adaptive radiotherapy. Sci Rep 12, (2022).





#### Application of AI in advanced image analysis



Wu, Y.-J.; et al. Radiomics in Early Lung Cancer Diagnosis: From Diagnosis to Clinical Decision Support and Education. Diagnostics 2022, Vol. 12, Page 1064 12, 1064 (2022).



**Personalised medicine** 



https://www.genosalut.com/en/news/healthy-lifestyle/what-is-personalised-medicine/





Martínez-García, M. & Hernández-Lemus, E. Data Integration Challenges for Machine Learning in Precision Medicine. Front Med (Lausanne) 8, 3082 (2022).







# Challenges for implementing AI in clinical routine: all that glitters is not gold

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1 MODEL BIAS	<ul> <li>Recording and reporting race, gender and demographic distributions.</li> <li>Active efforts to obtain representative, heterogenous data sets.</li> </ul>
2 DATA SECURITY	<ul><li>Federated learning.</li><li>Advanced encryption.</li></ul>
<b>3</b> DATA SIZE LIMITATIONS	<ul><li>Transfer learning.</li><li>Synthetic data.</li><li>Self supervised learning.</li></ul>
4 VARIABLE METHODOLOGY STANDARDS	<ul> <li>Peer-reviewed publication using AI frameworks (e.g. SPIRIT-AI)</li> <li>External-validation.</li> <li>Prospective studies and RCTs.</li> </ul>

Hunter, B., Hindocha, S. & Lee, R. W. The Role of Artificial Intelligence in Early Cancer Diagnosis. Cancers 2022, Vol. 14, Page 1524 14, 1524 (2022).





# Facing data size limitations: Transfer learning



Narayan Das N. et al. Automated Deep Transfer Learning-Based Approach for Detection of COVID-19 Infection in Chest X-rays. IRBM 43: 114-119 (2022)





## Facing data size limitations: Synthetic images



**Real images** 













## Facing data size limitations: Triplet networks



SigNet: Convolutional Siamese Network for Writer Independent Offline Signature Verification





#### **Explainable AI: the GradCAM**



