Data Science and AI for Medicine Training School

TRAINING: Application of Deep Learning in Medical Imaging (Radiology)

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GEFÖRDERT VOM
Bundesministerium für Forschung, Technologie und Raumfahrt

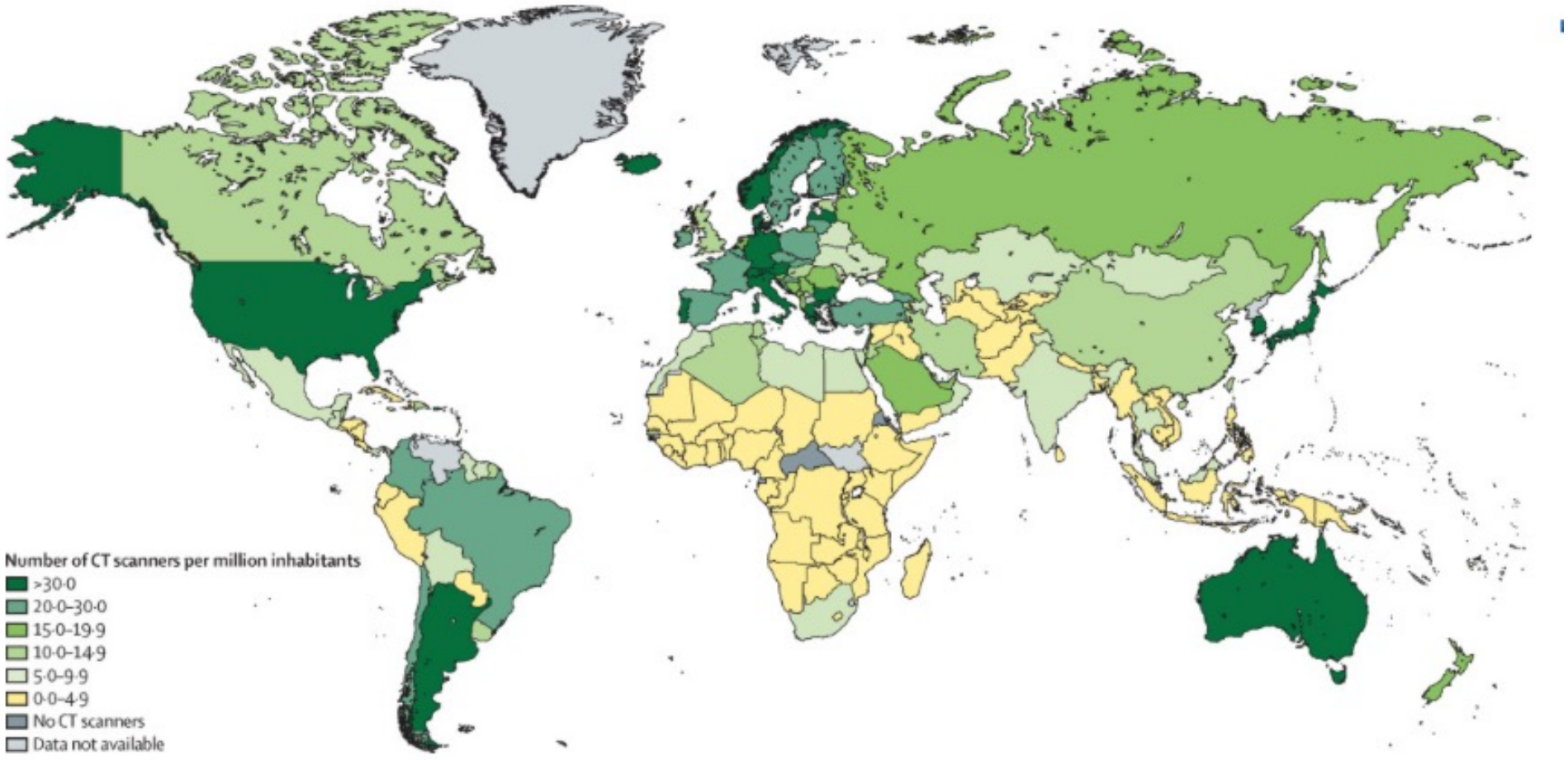
SACHSEN
Diese Maßnahme wird gefördert durch die Bundesregierung aufgrund eines Beschlusses des Deutschen Bundestages. Diese Maßnahme wird mitfinanziert durch Steuermittel auf der Grundlage des von den Abgeordneten des Sächsischen Landtags beschlossenen Haushaltes.


Deep Learning is everywhere...


And so is
Radiology!


Radiology in Medicine
Imaging modalities
Applications of Radiology in AI
Hands-On Session

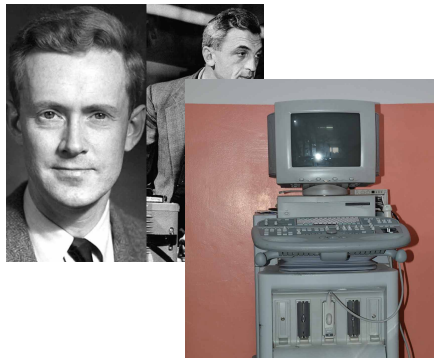
Radiology in Medicine: how every is everywhere?

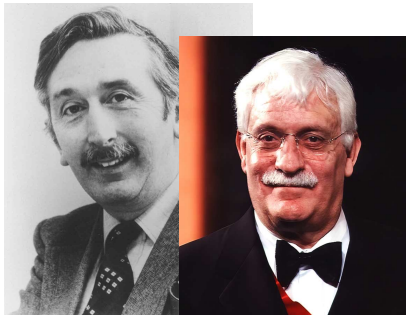


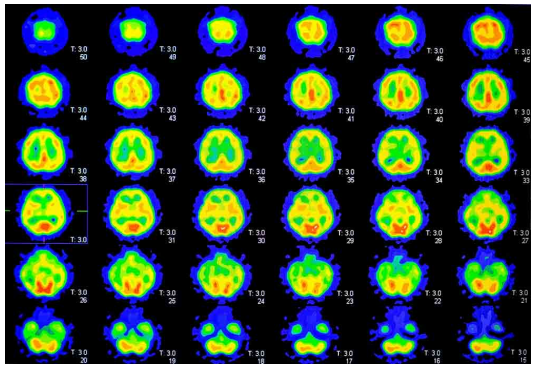
CT scan maps from Hricak et al. The Lancet Oncology (2021). 22(4): E136-E172

Radiology in Medicine: history and definition

Radiology: leverage of human body imaging for treatment guidance and diagnosis







1895-1896
Discovery of X-rays and radioactivity[1]

1914-1918
Film used for radiology
Usage in WWI

1946-1958
Discovery of NMR
Usage of ultrasound in gynecology

1970s-1980s
First CT and MRI images

1990s+
Refinement of radiological technologies[2]

X-rays source:
Röntgen, Wilhelm "A new type of Ray",1895
FMRI photo:
Belliveau et al. 1991, Science ,254(5032): 716-9

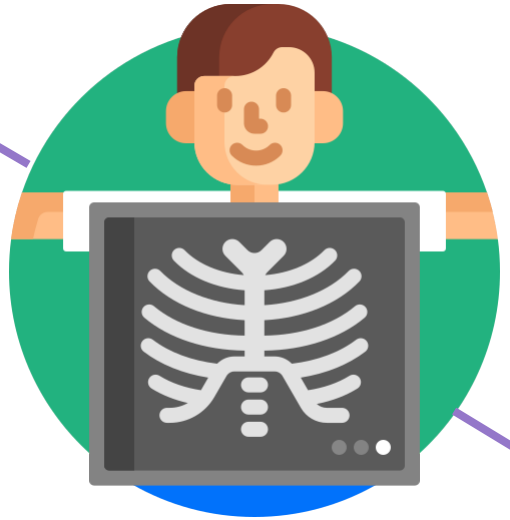
Radiology in Medicine: subtypes

Non-invasive

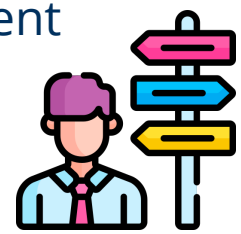
Diagnostic Radiology

Produces reports

Indirect radiologist involvement



Direct radiologist involvement



Guidance of concurrent procedures

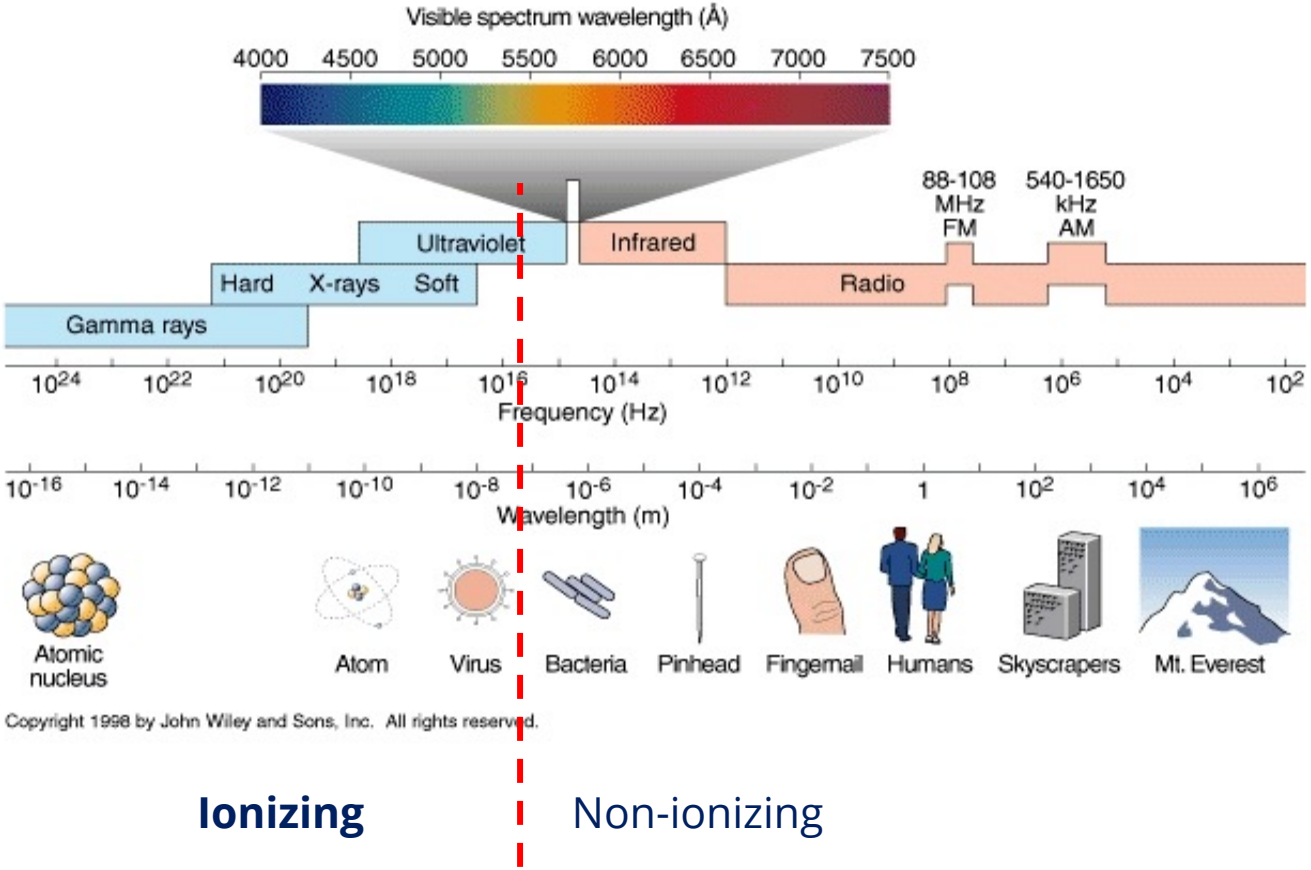
Interventional Radiology

Sedation

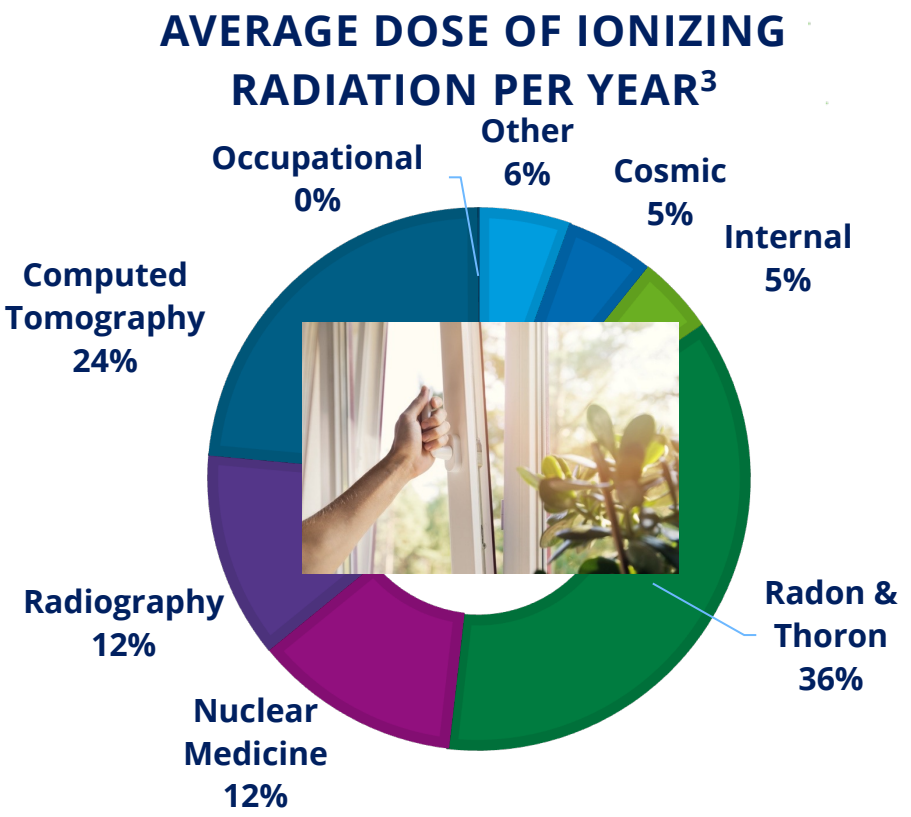

Radiology in Medicine
Imaging modalities
Applications of Radiology in AI
Hands-On Session

Imaging modalities: brief summary of radiation

Radiation: emission/transmission of energy through space via waves or particles

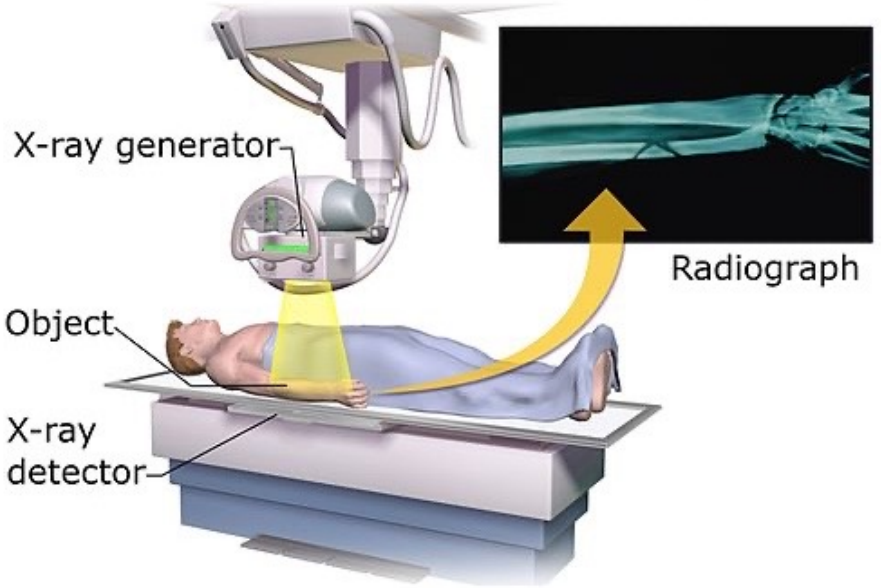


Ionizing | Non-ionizing



Data for dose of radiation:
US Environmental Protection Agency "Radiation Sources and Doses" https://www.epa.gov/radiation/radiation-sources-and-doses

Imaging modalities: projectional radiography



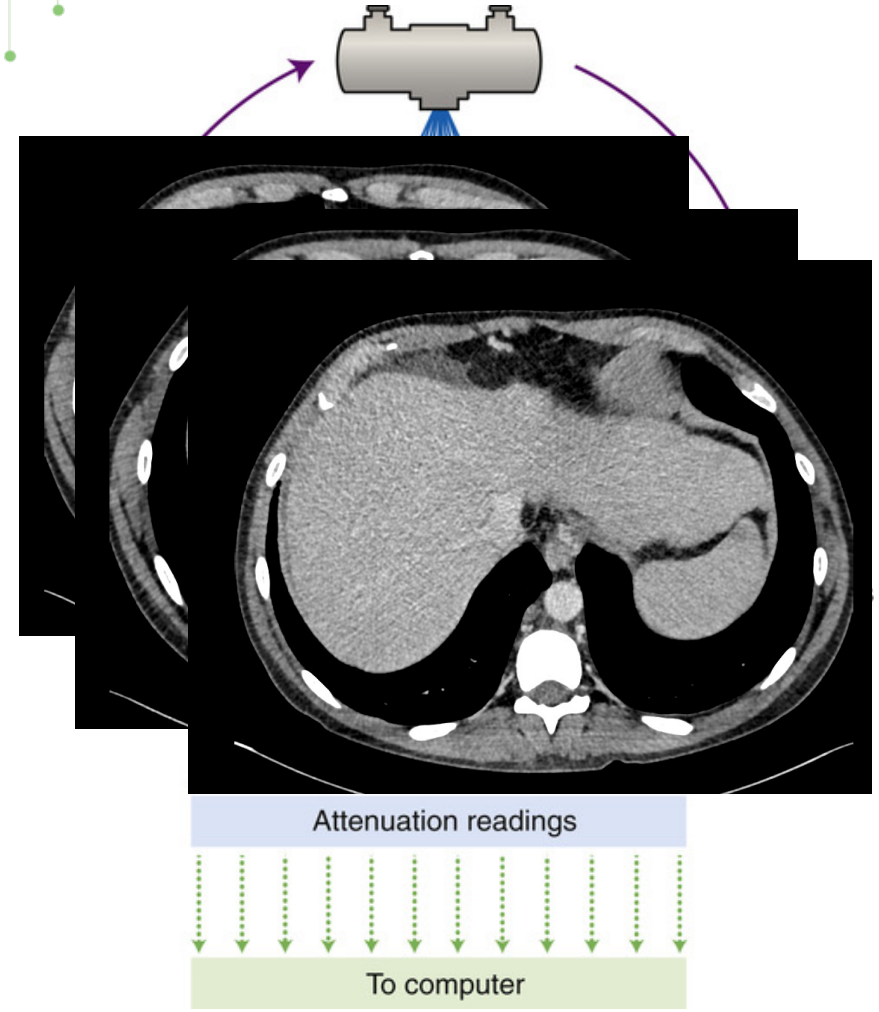
X-rays are ionising sources of radiation.
Small doses used to produce 2D images of body structures

Contrast can be limited due to overlapping of structures in one single view

Radiography is used to diagnose broken bones, foreign objects in soft tissue or screen for infections

Oldest and most used form of medical imaging

Imaging modalities: computerised tomography



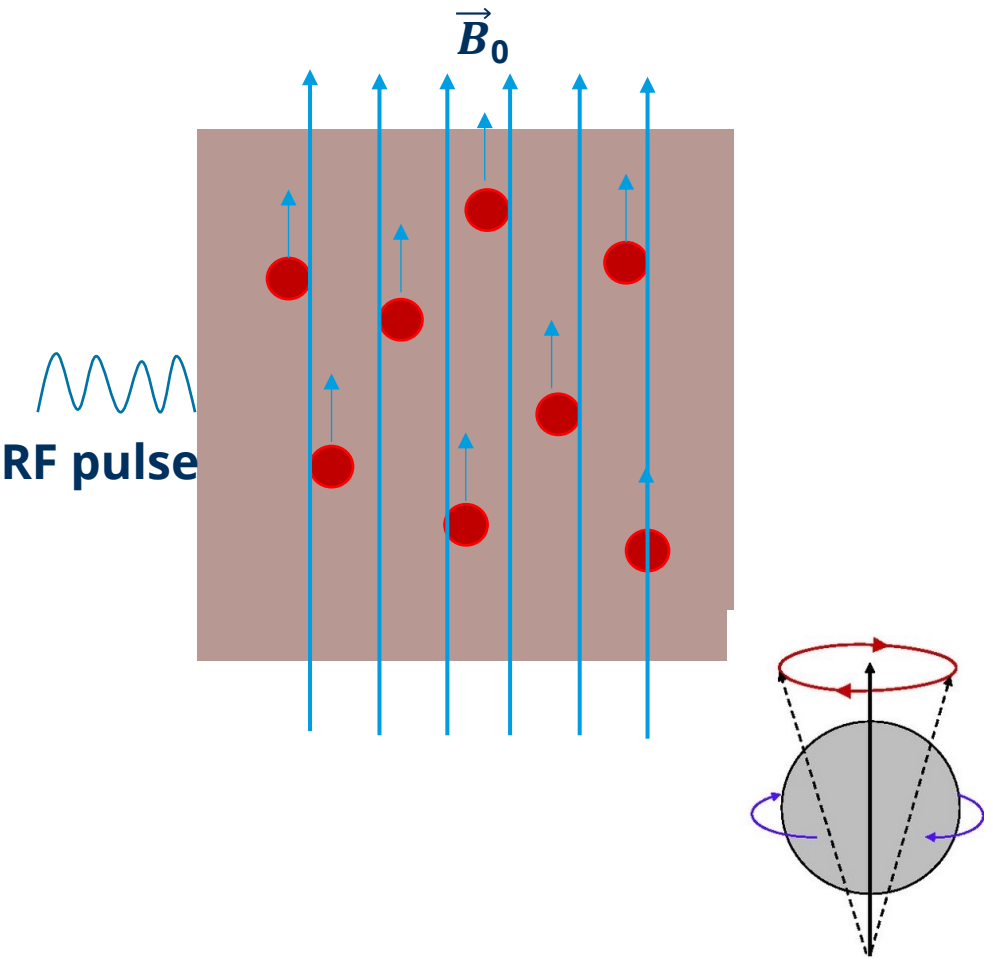
More radiation than X-rays, but allows for 3D scanning of the body/area of interest

Contrast is used intravenously to highlight different parts of the anatomy in real time

Allows for locating lesions within the body, assess sizes and make first impressions on a diagnosis

CT units have physical meaning, related to the attenuation of water.

Imaging modalities: magnetic resonance imaging



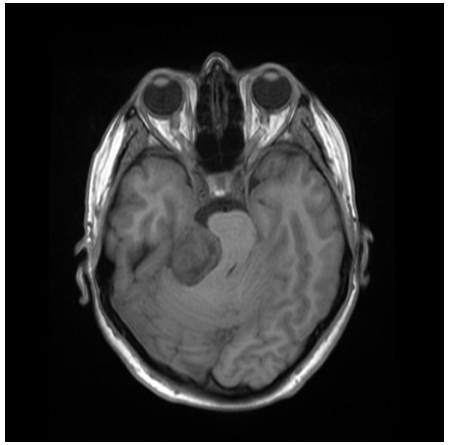
MRI does not produce ionizing radiation, it is based on nuclear magnetic resonance from hydrogen nuclei (protons)

MRI is very very diverse. Sequences use different resonance aspects, highlighting different phenomena

MRIs are better at contrast resolution than CTs but lower at spatial resolution

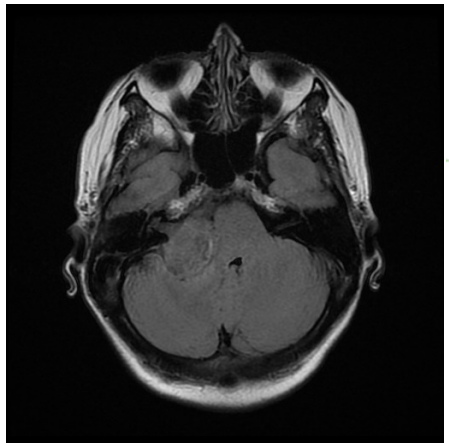
MRI units are dimensionless and can vary from person to person for the same exam.

Imaging modalities: magnetic resonance imaging

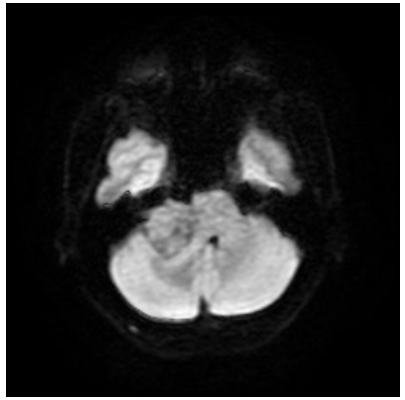


T1-weighted

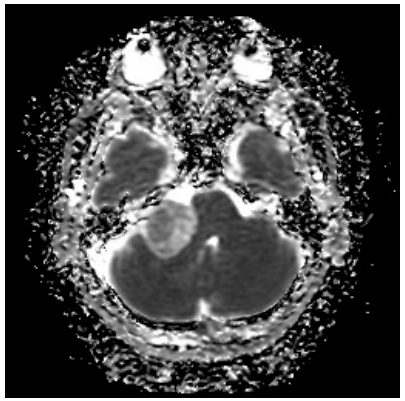
T2-weighted



FLAIR



Diffusion-weighted



Apparent diffusion weighted


Radiology in Medicine
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Hands-On Session

Applications of Radiology in AI

“Radiologists will be obsolete in 5 years”

George Hinton, 2016, Godfather of AI and Nobel prize in Physics.
Not a radiologist

Applications of Radiology in AI: the need for AI

Prevalence of burnout amongst German radiologists: A call to action

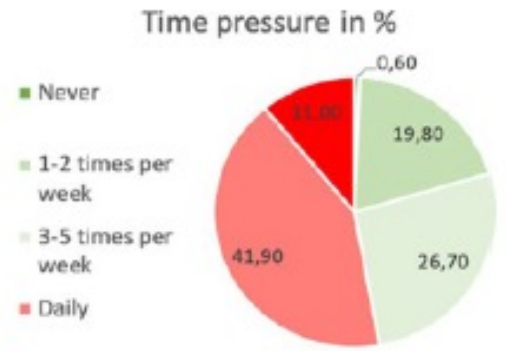
EUROPEAN SOCIETY OF RADIOLOGY

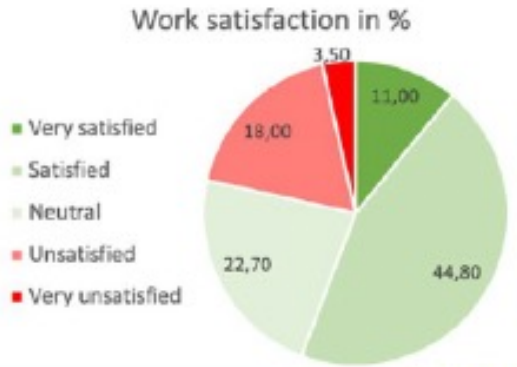
Burnout is prevalent among medical professionals, including radiologists

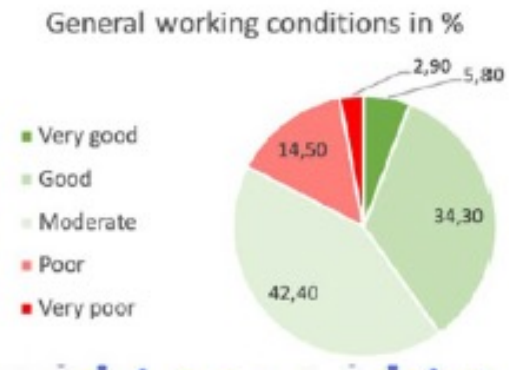
Distributed burnout focused questionnaires to members of the German Society of Radiology and Interventional Radiology

A burnout-rate of 76.7% was observed in 172 participants

Further observations included:







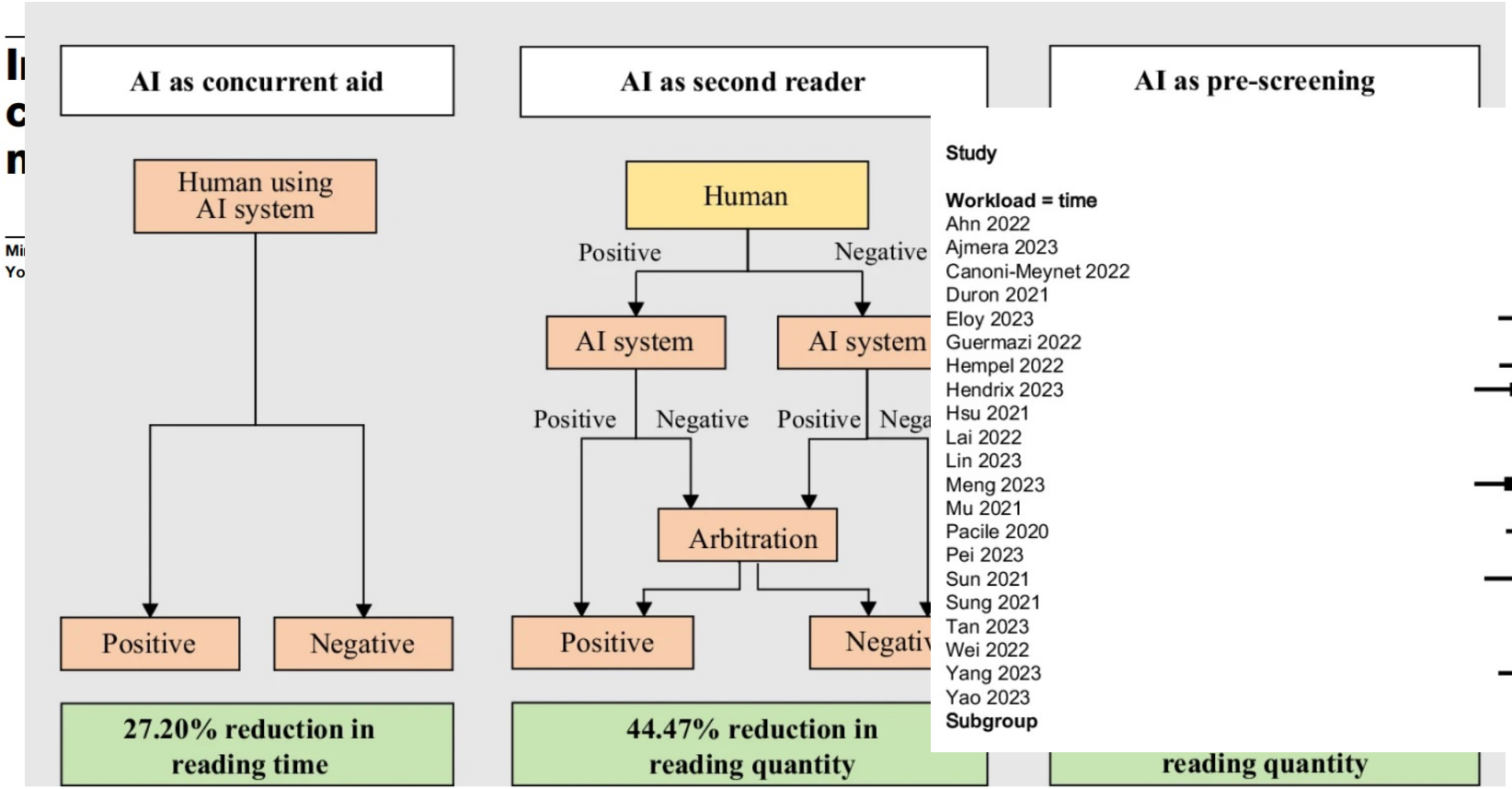
84	Data not available

Map of radiologsists from: https://harrison.ai/news/global-radiology-6-key-challenges-how-ai-can-help/

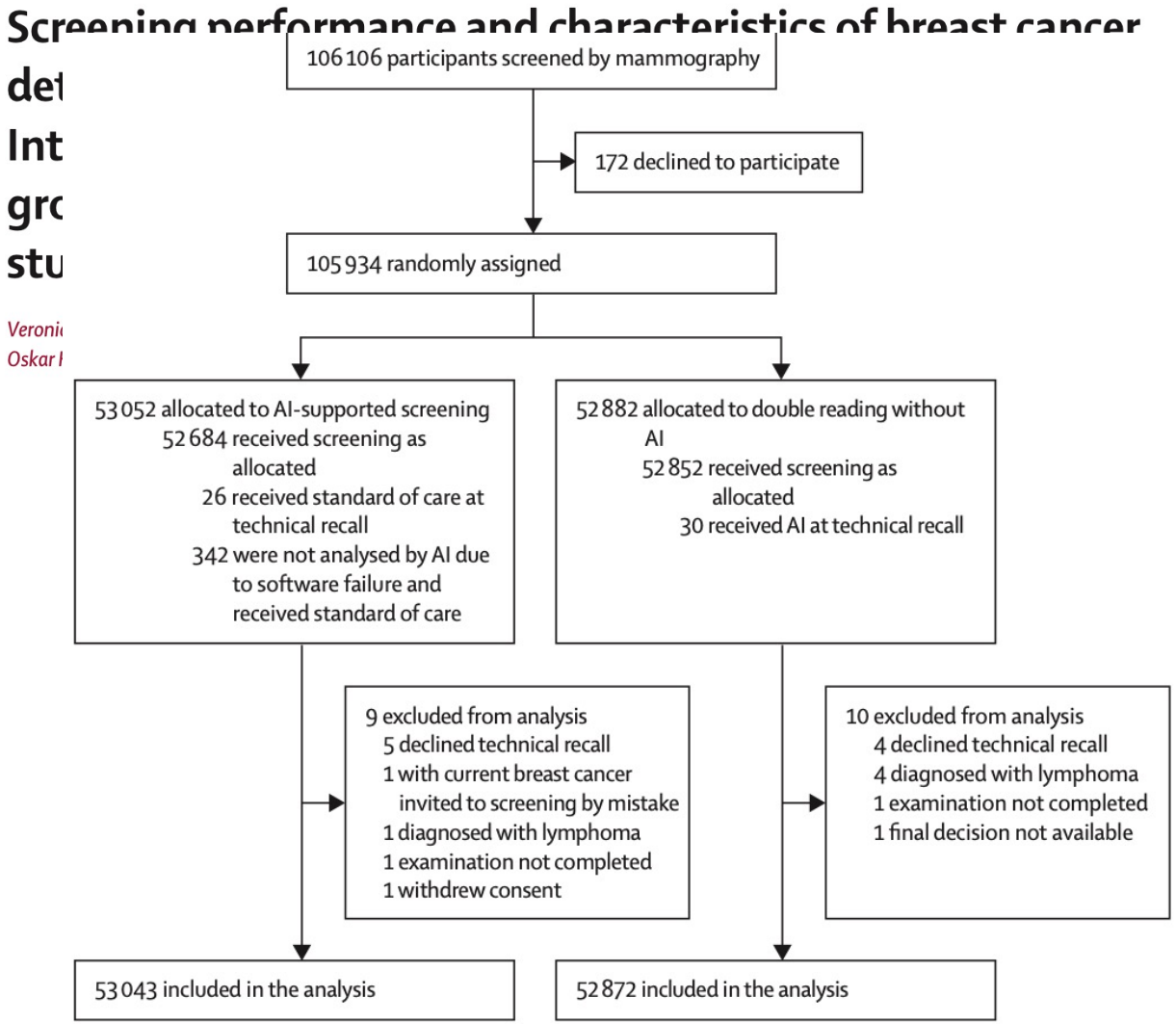
Burnout abstract:
Bastian, M. et al. European Radiology (2025).

Applications of Radiology in AI: synergistic fields

npj | digital medicine
Article
Published in partnership with Seoul National University Bundang Hospital



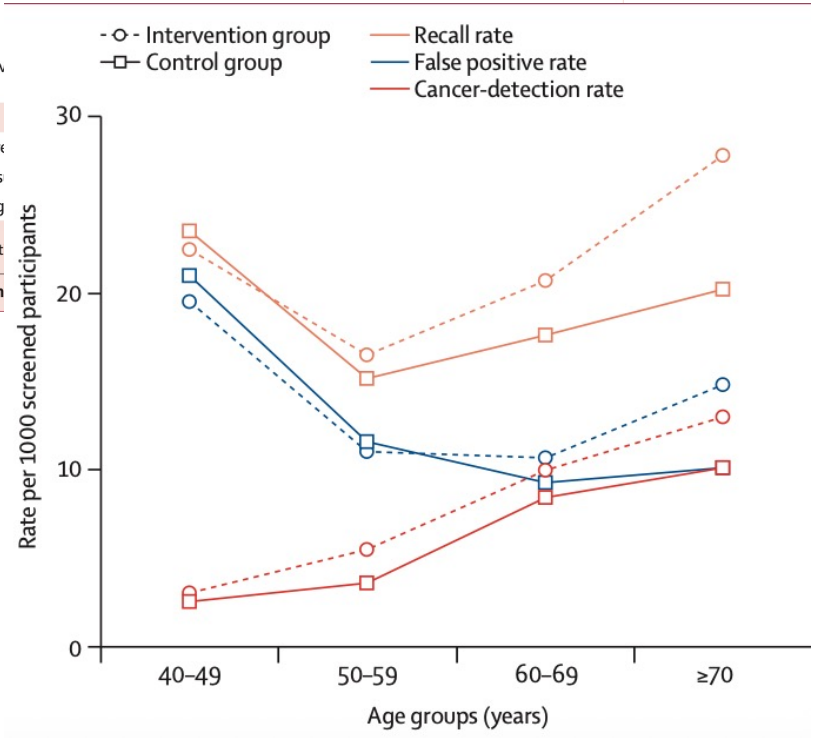
Applications of Radiology in AI: the MASAI trial



	Intervention group (n=53 043)	Control group (n=52 872)	Proportion ratio	p value
Early screening performance				
Number of recalls	1110	1027	..	..
Recall rate	2·1% (2·0–2·2)	1·9% (1·8–2·1)	1·08% (0·99–1·17)	0·084
Number of detected cancers	338	262	..	..
Cancer-detection rate, per 1000	6·4 (5·7–7·1)	5·0 (4·4–5·6)	1·29 (1·09–1·51)	0·0021
Number of false positives	772	765	..	..
False positive rate				
Positive predictive v				
Workload				
Number of screen re				
Number of consens				
Consensus meeting				

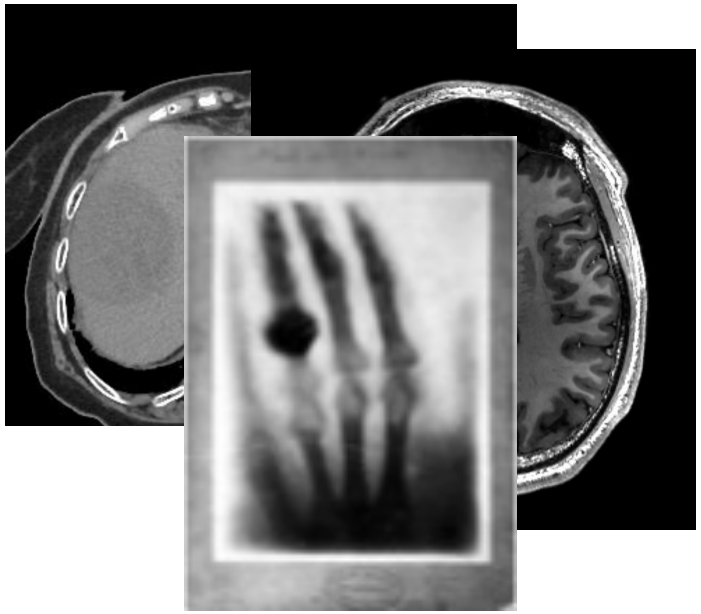
Data are n or point est

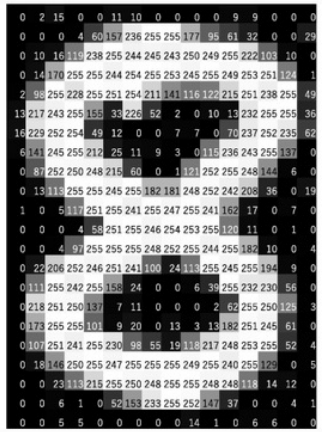
Table 2: Early screen

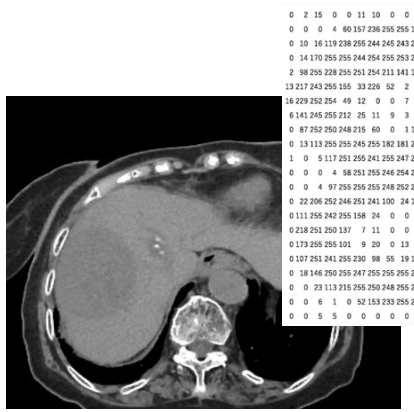


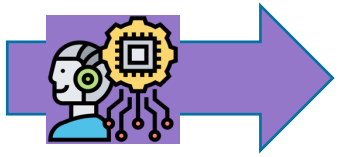
Images and data from:
Hernström et al. *The Lancet Digital Health* (**2025**). 7(3):E175-E178

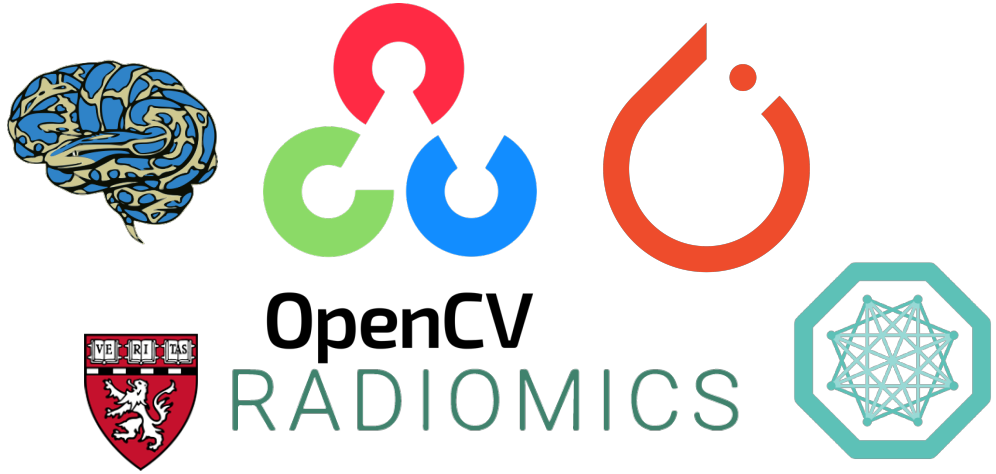
Applications of Radiology in AI: from data to insights











Applications of Radiology in AI: how is data used?

Radiology dataset (2D, 3D…)

Data Loading

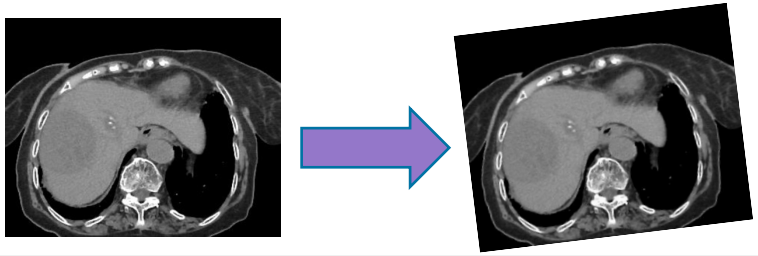
- Package to load images
- Functions to feed data to the model
- Augmentations on images

Model training

- Select parameters for training
- Choose architecture
- Make loops for training and tracking

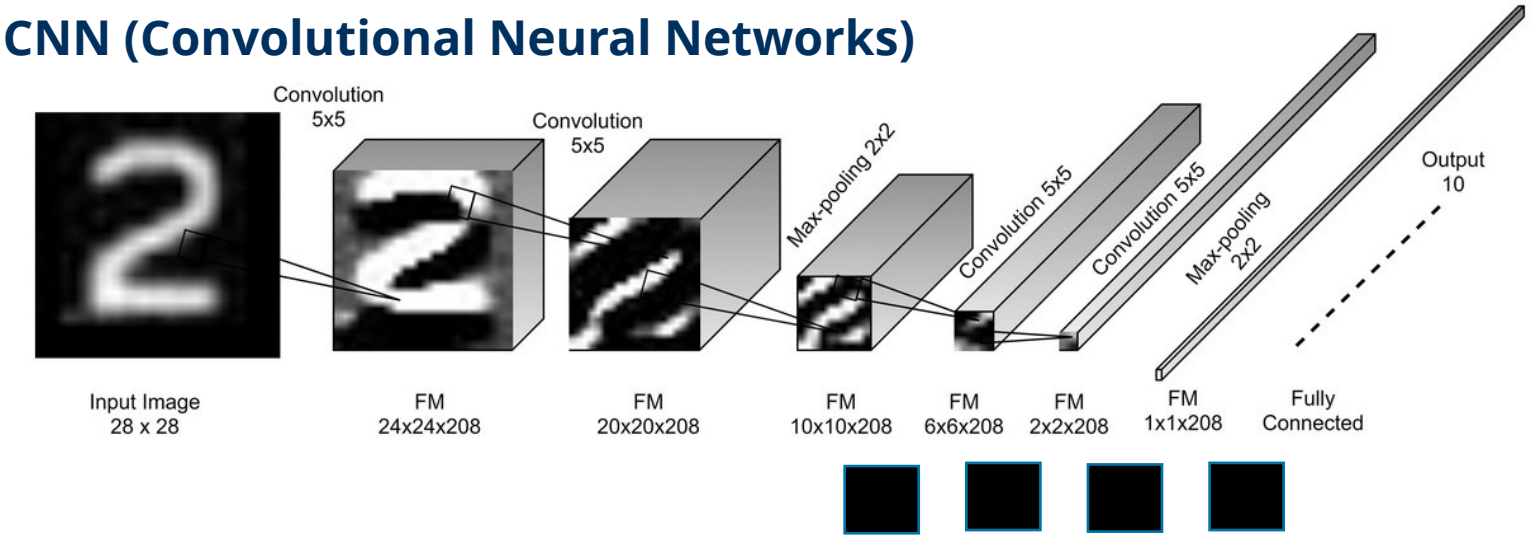
Test & evaluate

- Use different data to deploy model
- Test model through different metrics
- Explainability



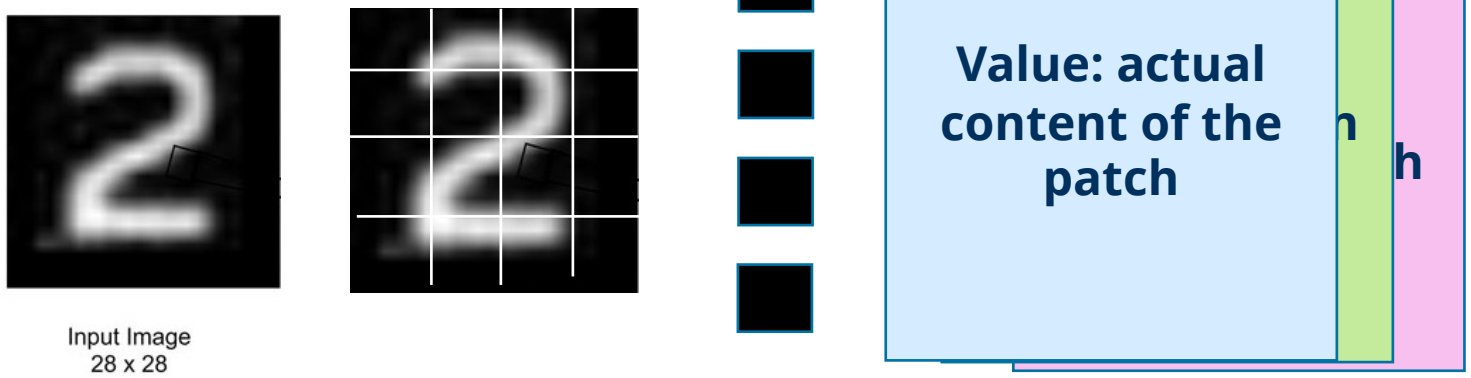
Applications of Radiology in AI: architectures

CNN (Convolutional Neural Networks)



Features based on relationships of **neighbouring** pixels through convolution

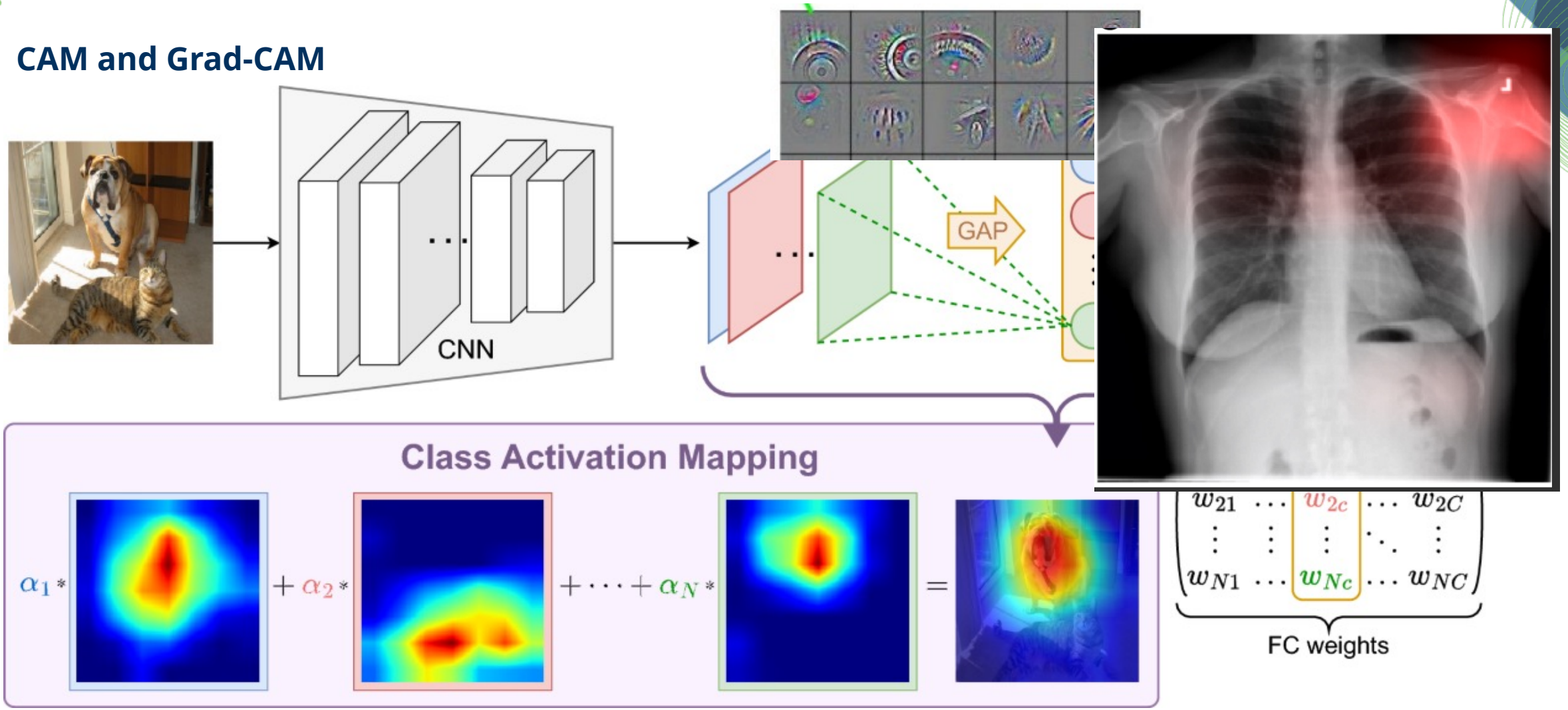
(Vision) Transformers



Features based on learned relationships between tokens, **very weak inductive bias**

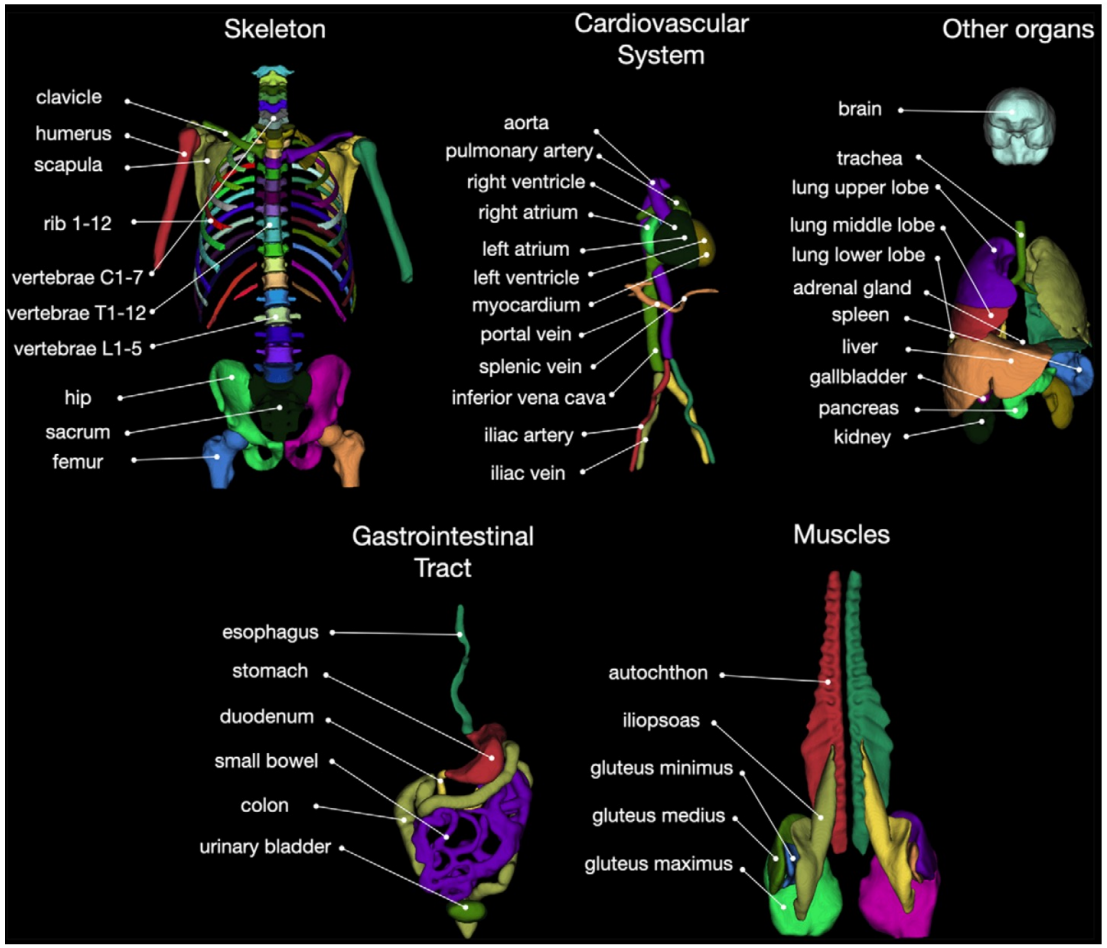
Applications of Radiology in AI: explainability

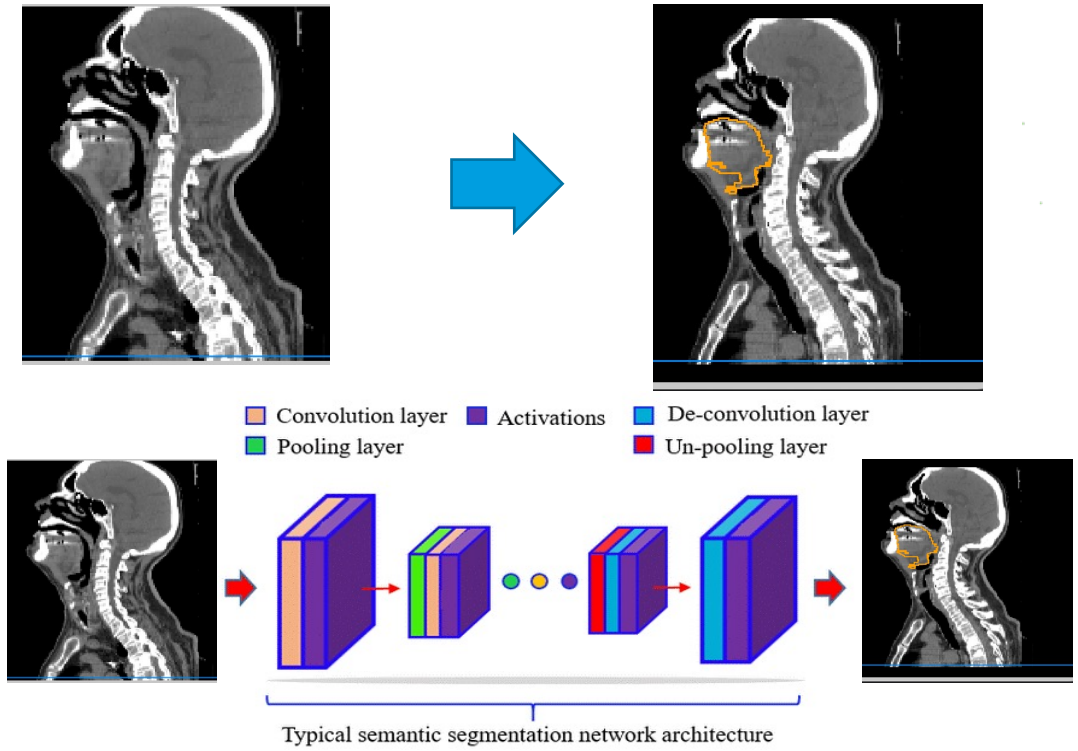
CAM and Grad-CAM



Cam schematix
Dugaecescu et al.. *Neural Computing and Applications* (2025). 3:14935-14970
X-rays:
Zech, J. et al. *PLOS Medicine* .(2019). 15(11): e1002683

Applications of Radiology in AI: segmentation





Segmentation Loss (Dice)

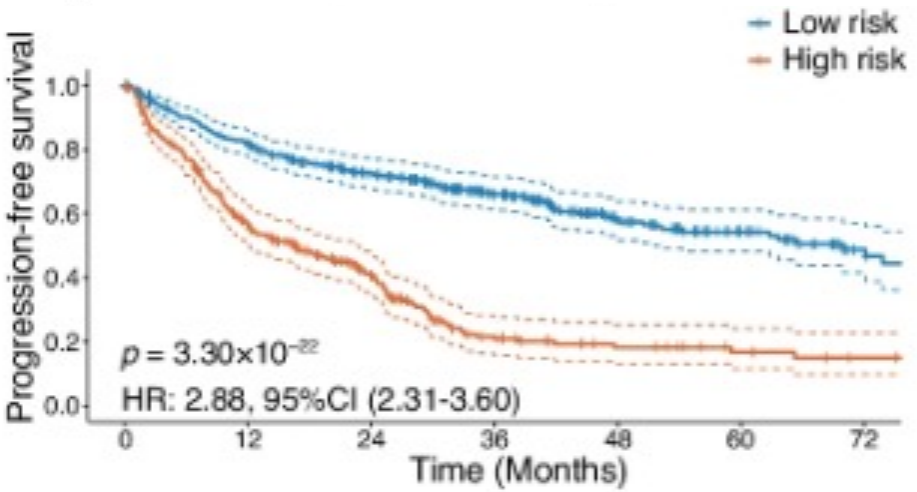
$$L_{dice} = 1 - \frac{2\sum_{n=1}^{N} t_n y_n}{\sum_{n=1}^{N} (t_n + y_n)}$$

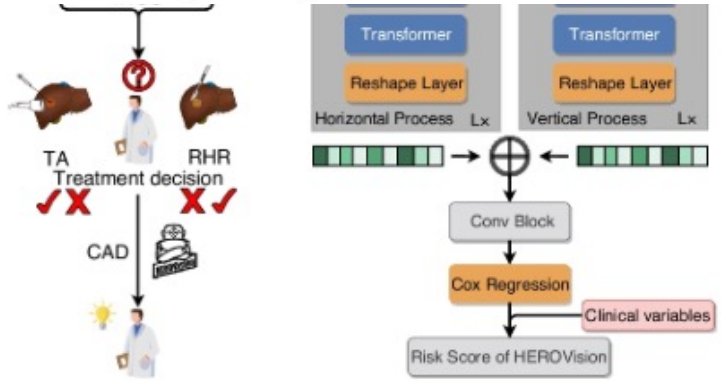
Segmentation tool and image of body:
Wasserthal., J. et al. *Radiology AI* (**2023**). 5(5)
H&N images: *Welch, M et al. (2023). Computed Tomography Images from Large Head and Neck Cohort (RADCURE) (Version 4) The Cancer Imaging Archive. https://doi.org/10.7937/J47W-NM11*

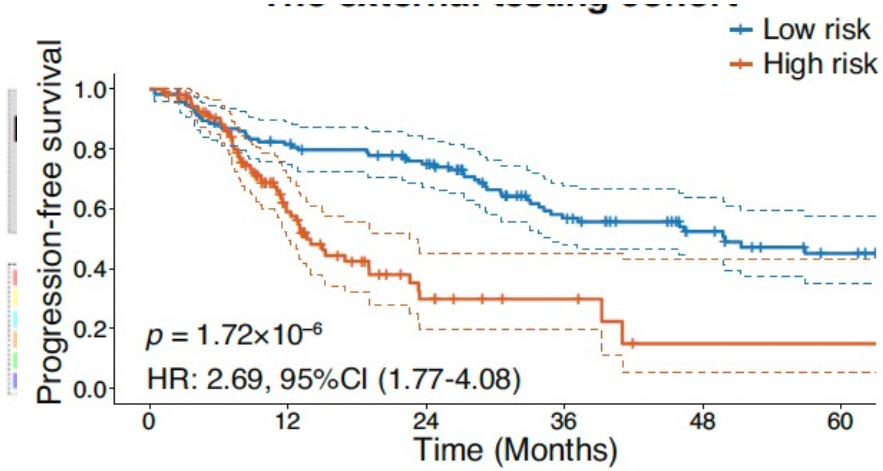
Applications of Radiology in AI: prognosis

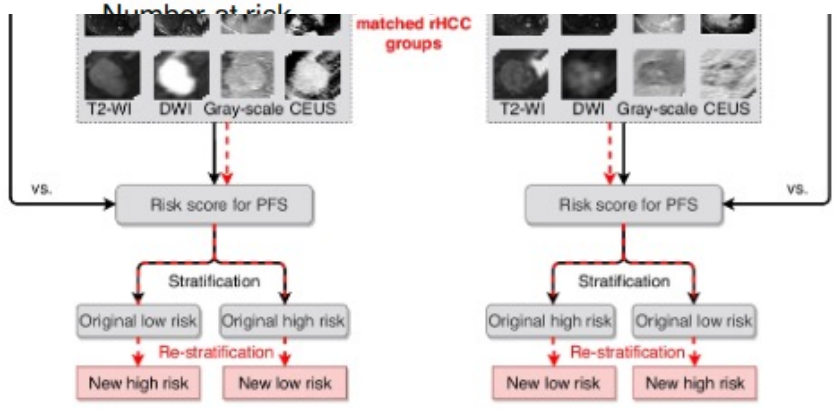
Article | Open access | Published: 01 May 2025

Vision transformer-based model can optimize curative-intent treatment for patients with recurrent hepatocellular carcinoma









Conclusions

- Radiology is a long-lived field with an early adoption of electronic technology
- Radiological images are varied and diverse, making Radiology a complex field.
- The complexity, number and link of radiological images with diseases makes them a rich source f informative data for modeling
- Radiology can benefit from AI, reducing workloads and enhancing radiologist readings
- Ai in Radiology is an ongoing field of research. There is evolution in architectures, training styles and applications

Now on to the hands-on session!