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Applications of AI in clinical nuclear medicine

David Kersting, University Hospital Essen, University of Duisburg-Essen

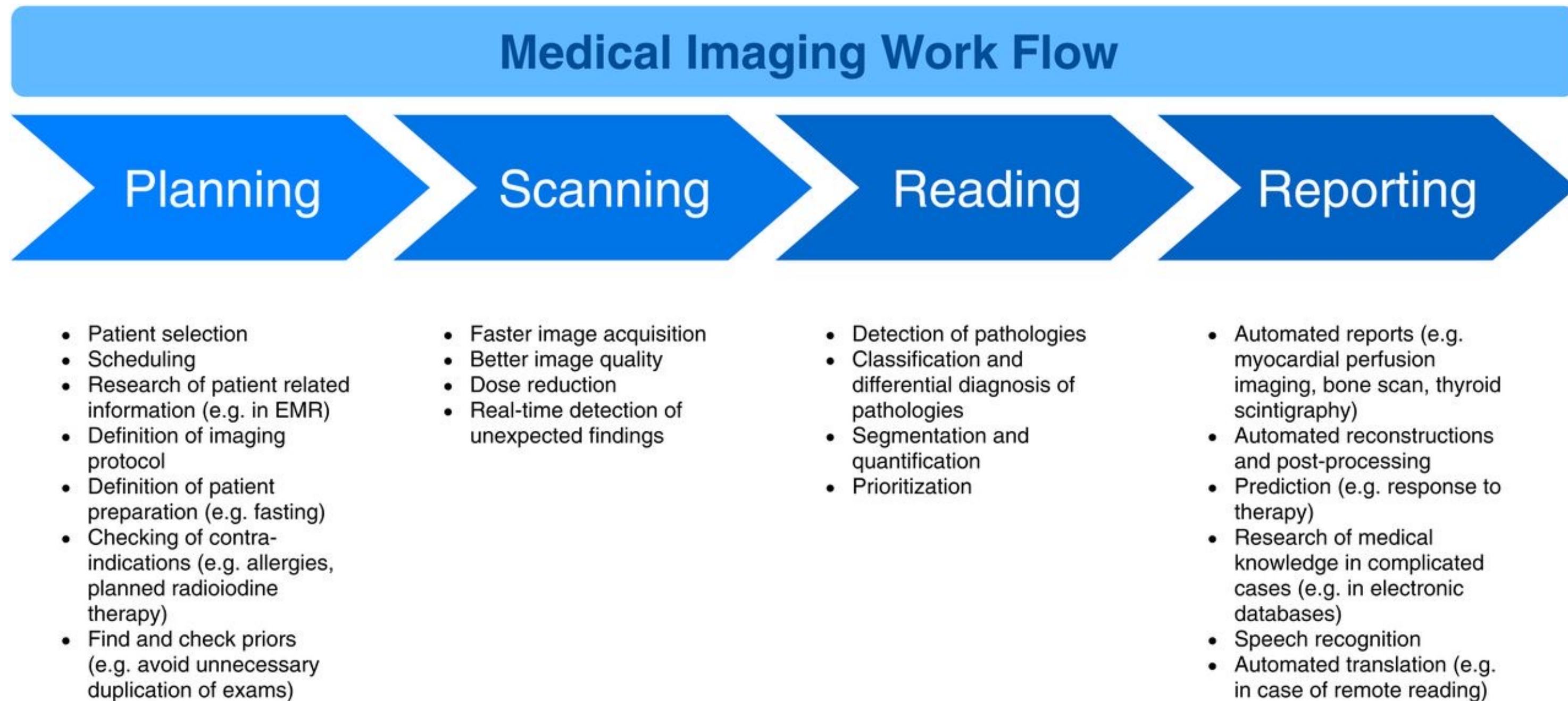


Artificial Intelligence

- Video removed



Workflow and improvements

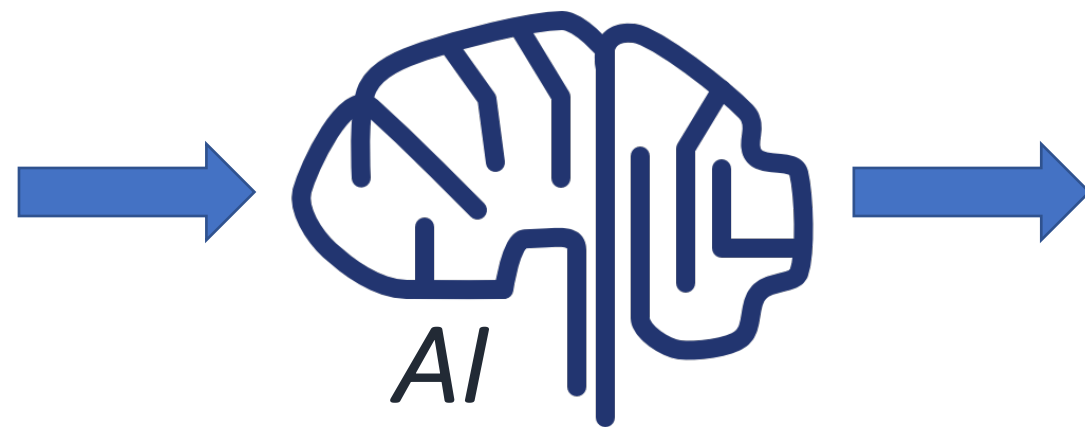
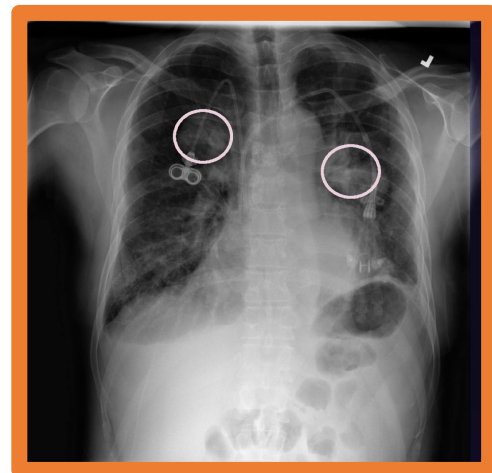


Basic features of AI in medical imaging

Applications of AI in clinical nuclear medicine

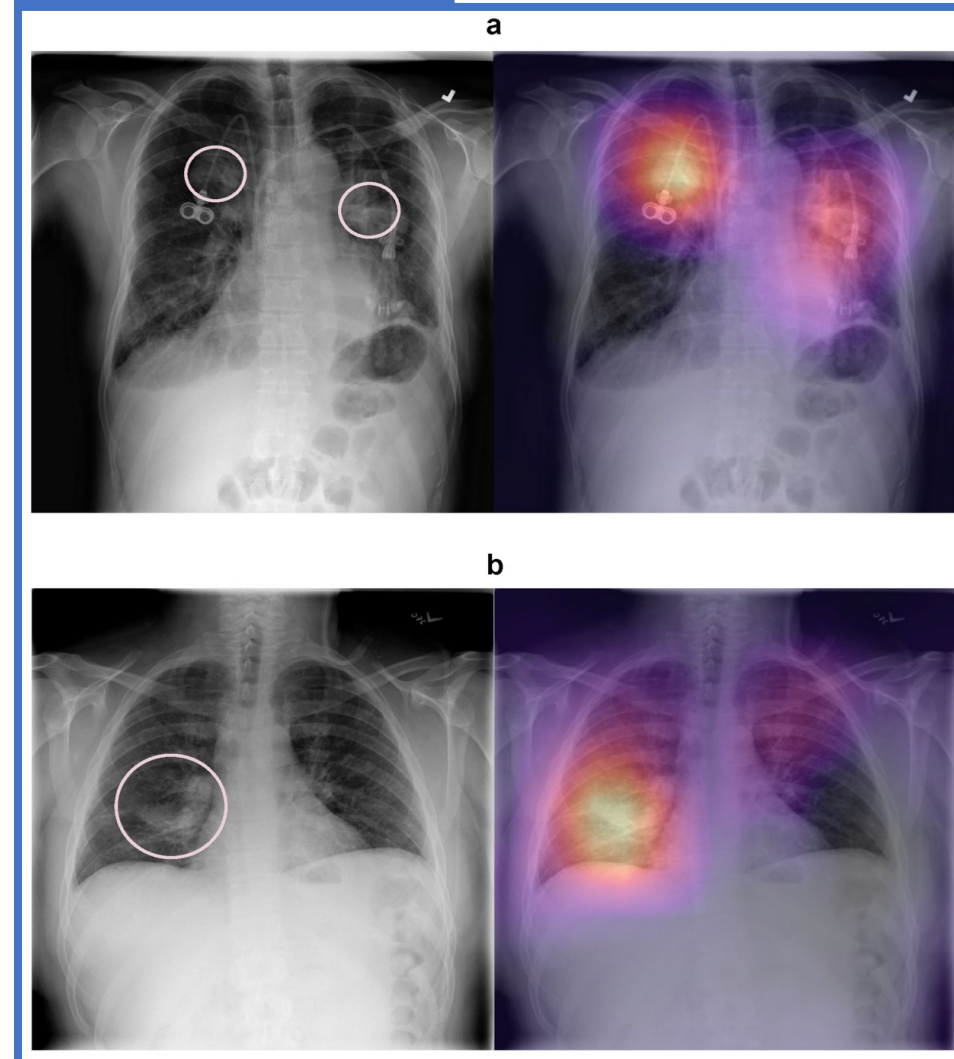


AI in medicine

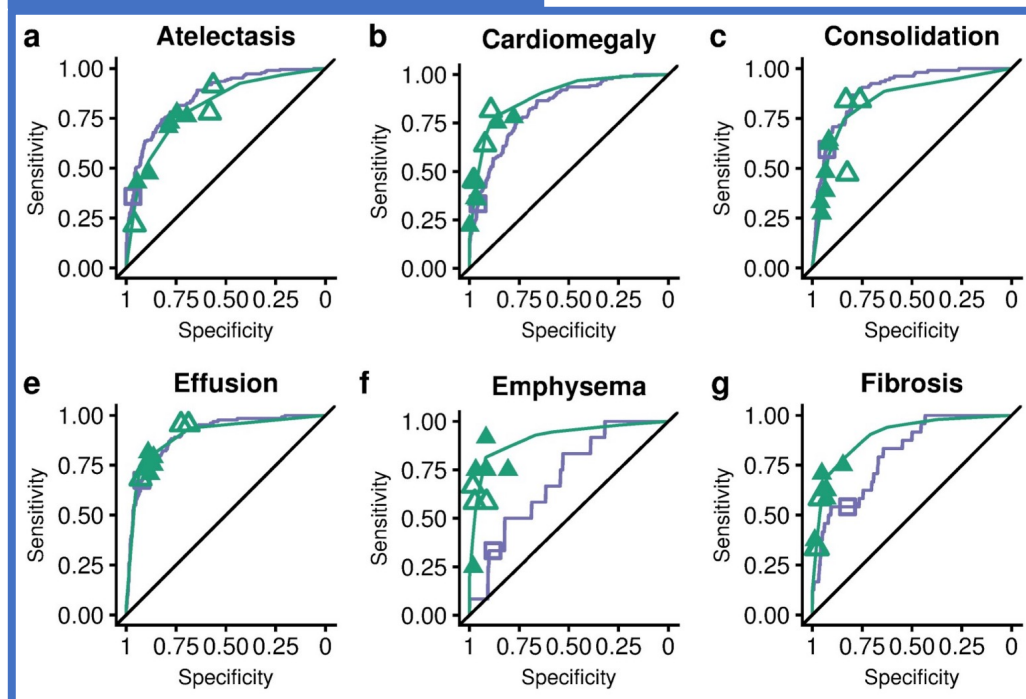


- „Pneumonia“
- „Lung cancer“
- ...

Examples:



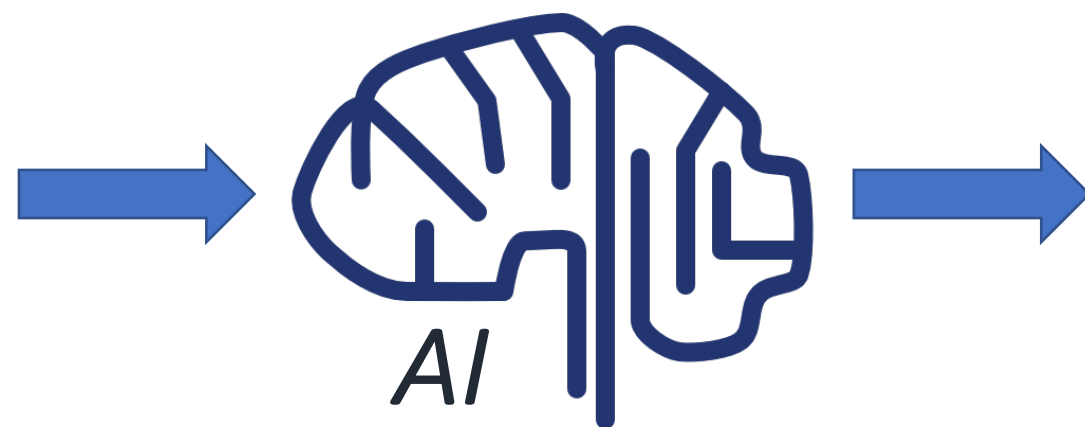
Accuracy



Rajpurkar, Pranav, et al.
"Deep learning for chest
radiograph diagnosis: A
retrospective comparison of
the CheXNeXt algorithm to
practicing radiologists." PLoS
medicine 15.11 (2018):
e1002686.

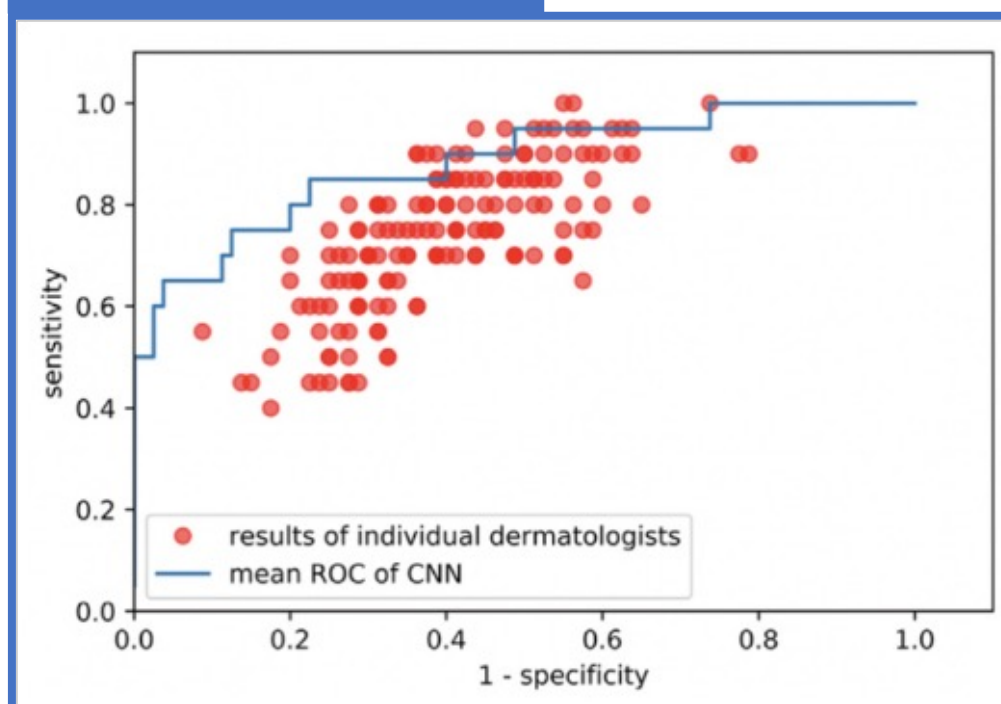


AI in medicine



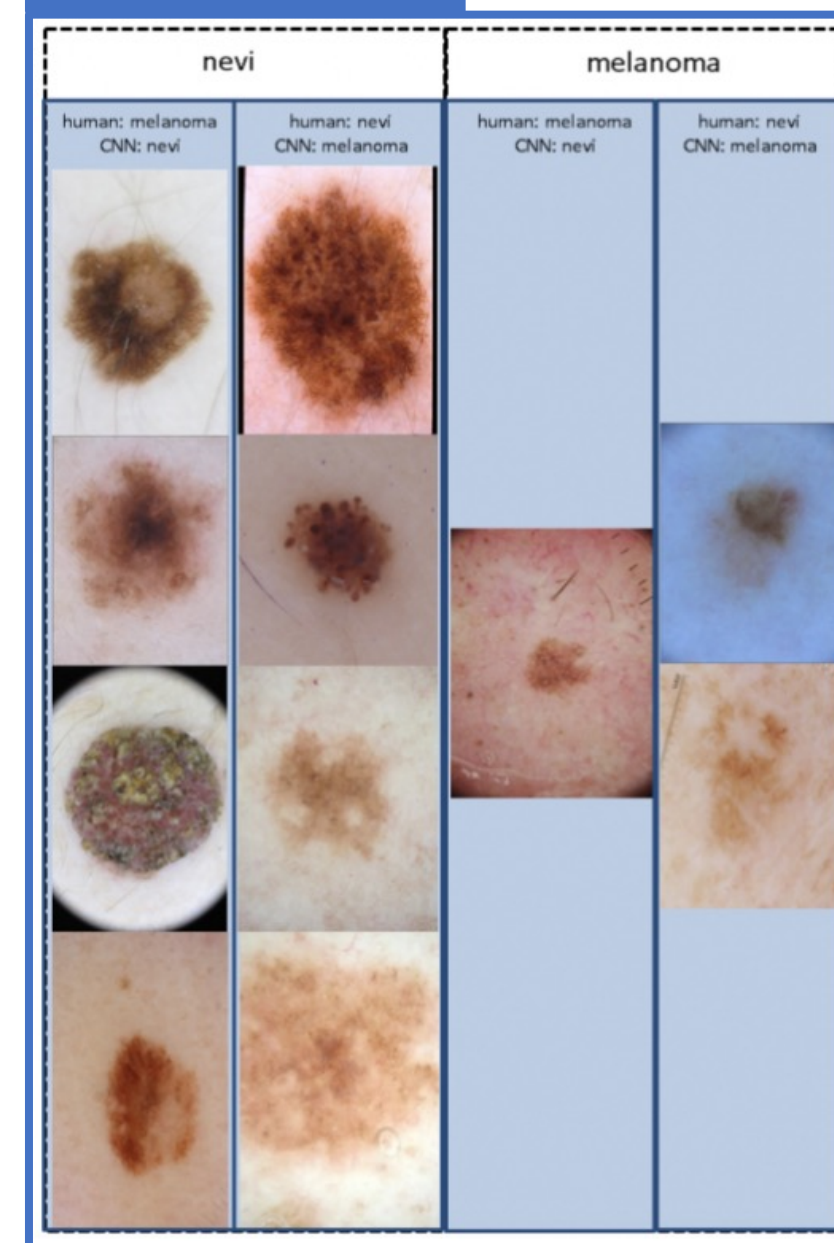
Skin cancer
• „yes“
• „no“

Accuracy

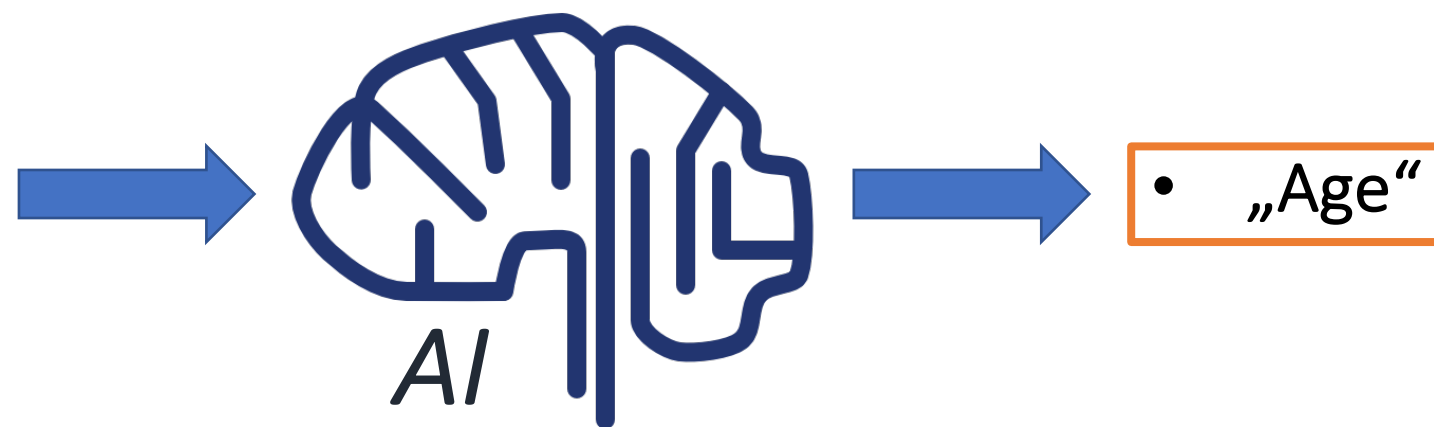


Brinker, Titus J., et al.
"Deep learning
outperformed 136 of 157
dermatologists in a head-to-
head dermoscopic
melanoma image
classification
task." *European Journal of
Cancer* 113 (2019): 47-54.

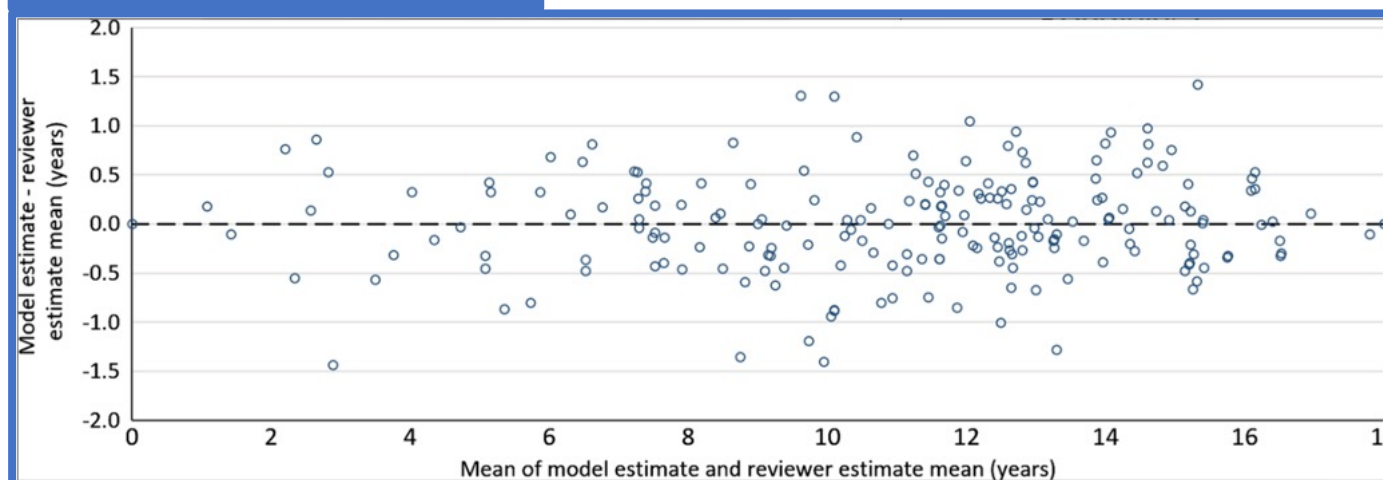
Examples:



AI in medicine



Accuracy

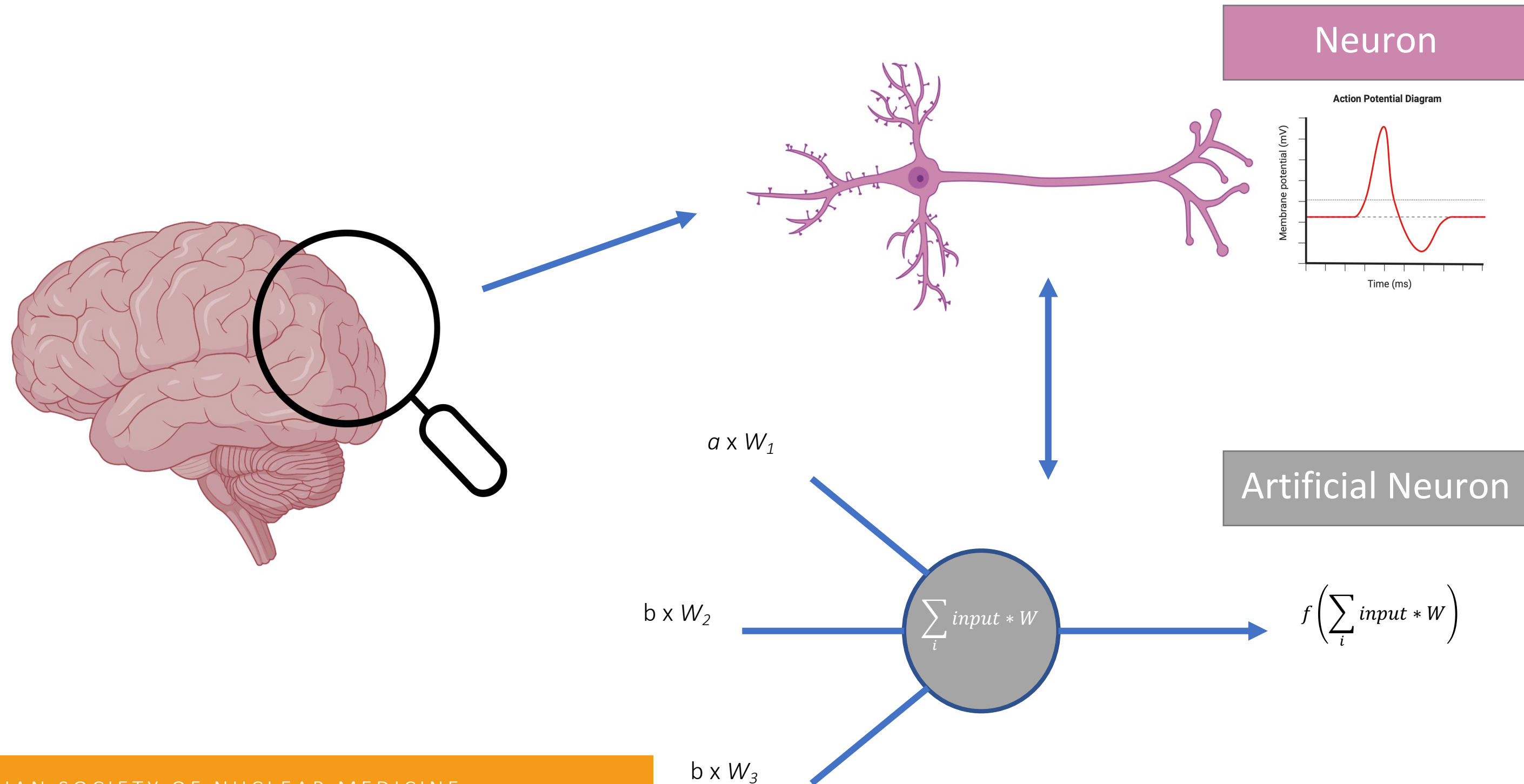


Larson, David B., et al.
"Performance of a deep-learning neural network model in assessing skeletal maturity on pediatric hand radiographs." *Radiology* 287.1 (2018): 313-322.

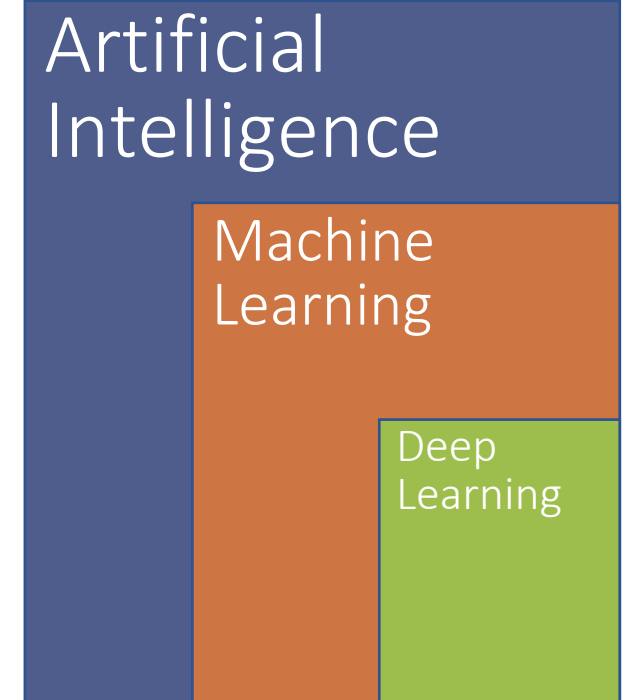
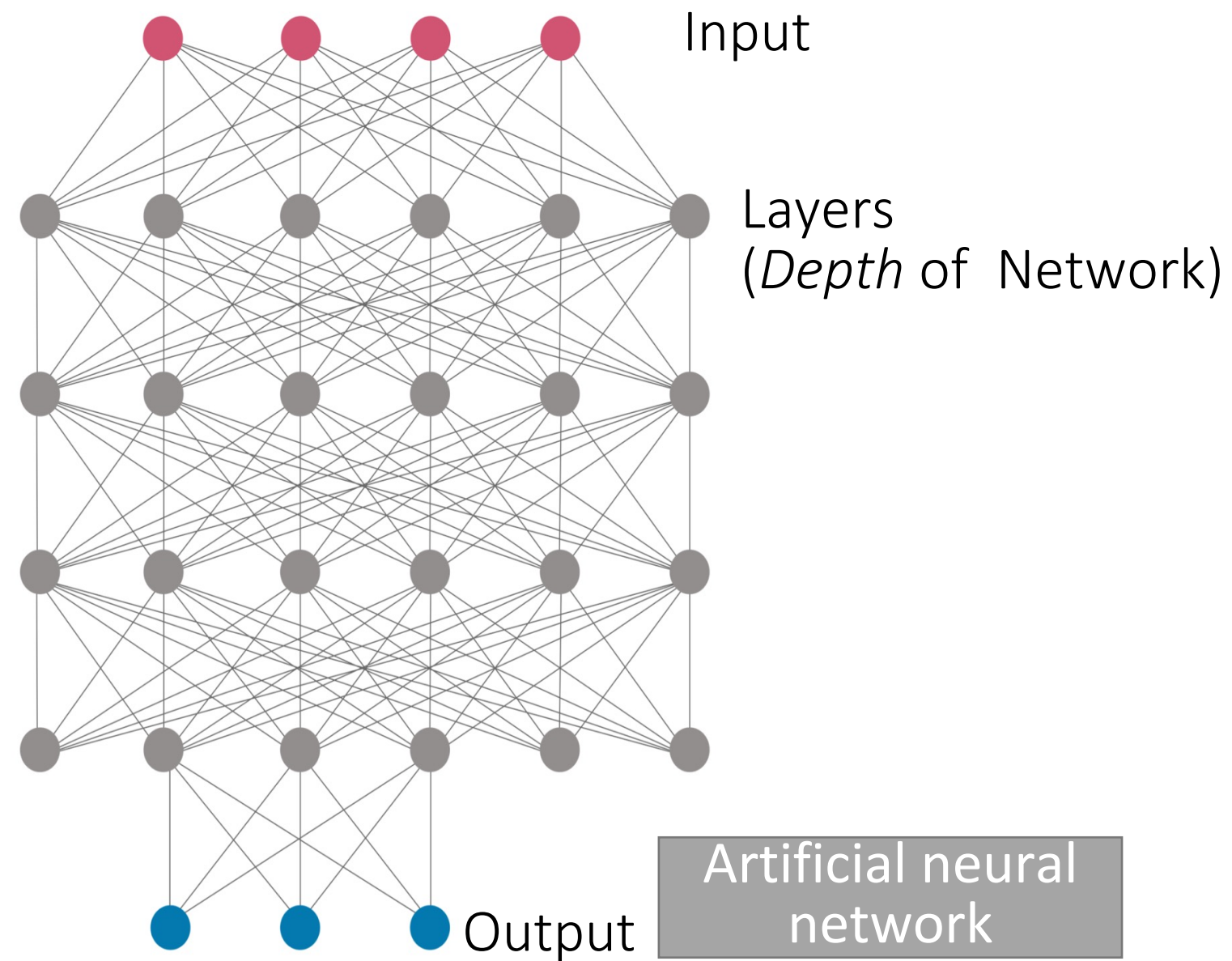
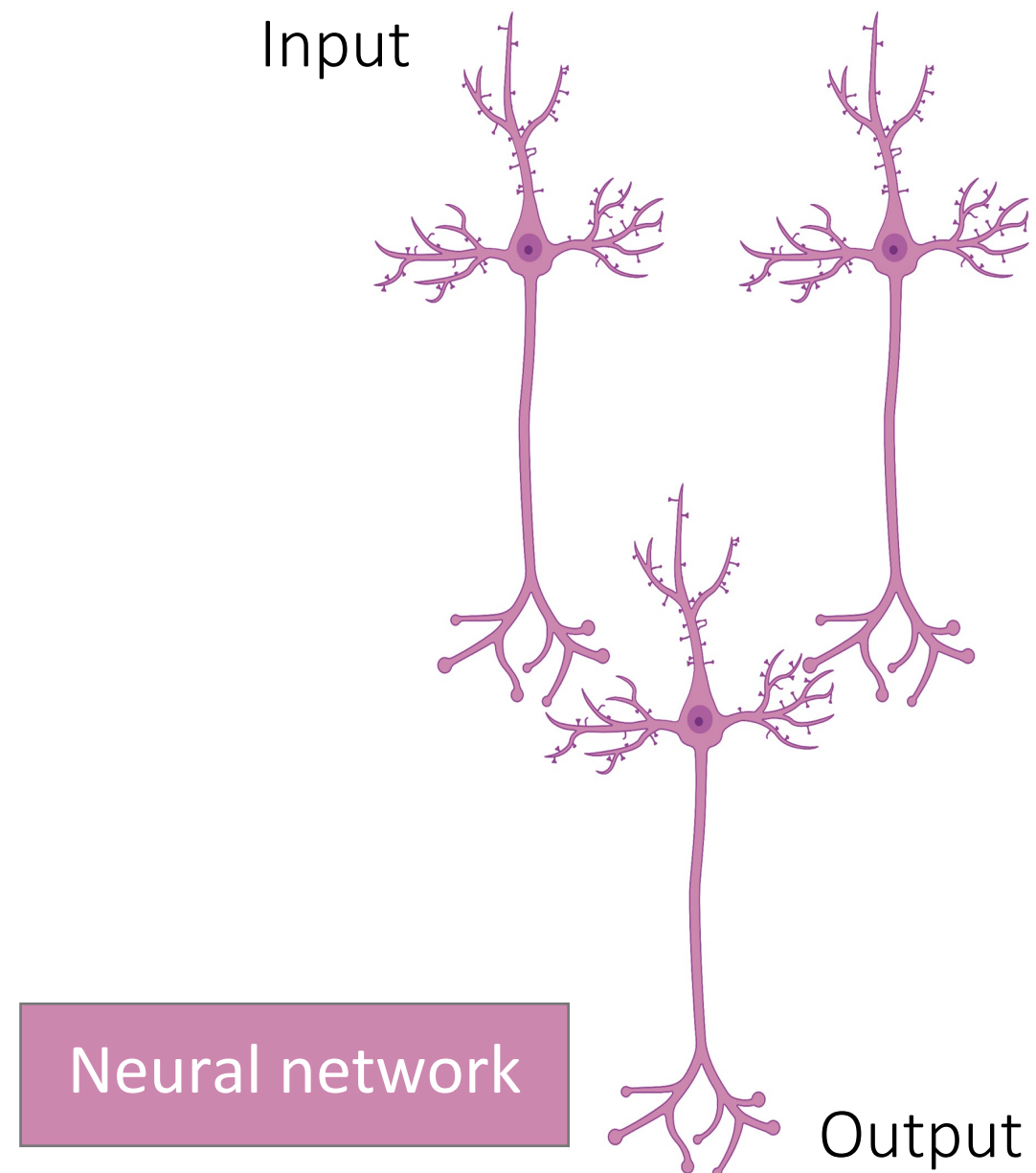
Examples:



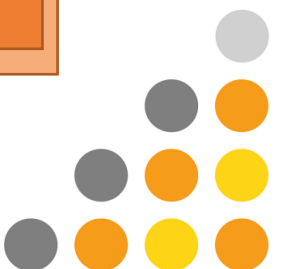
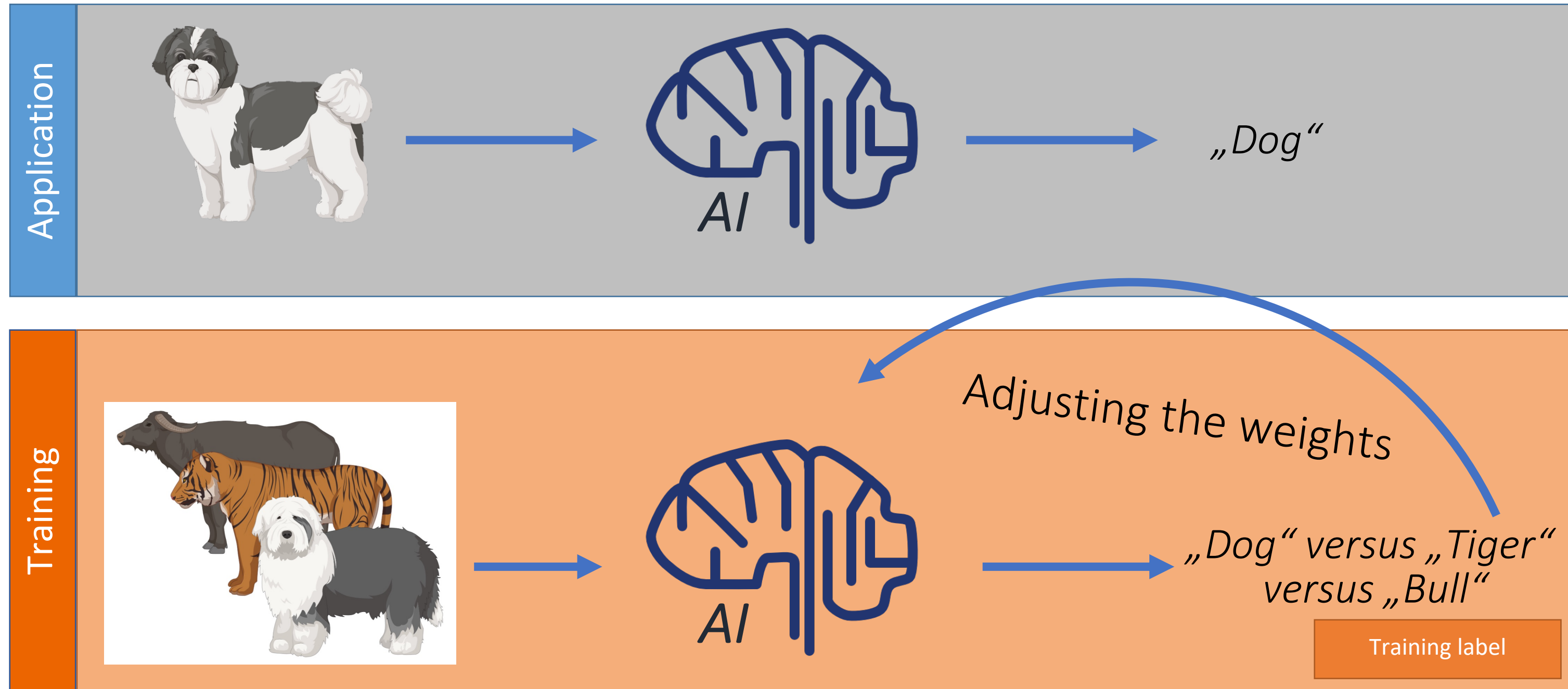
How does AI work?



How does AI work?



How does AI work?

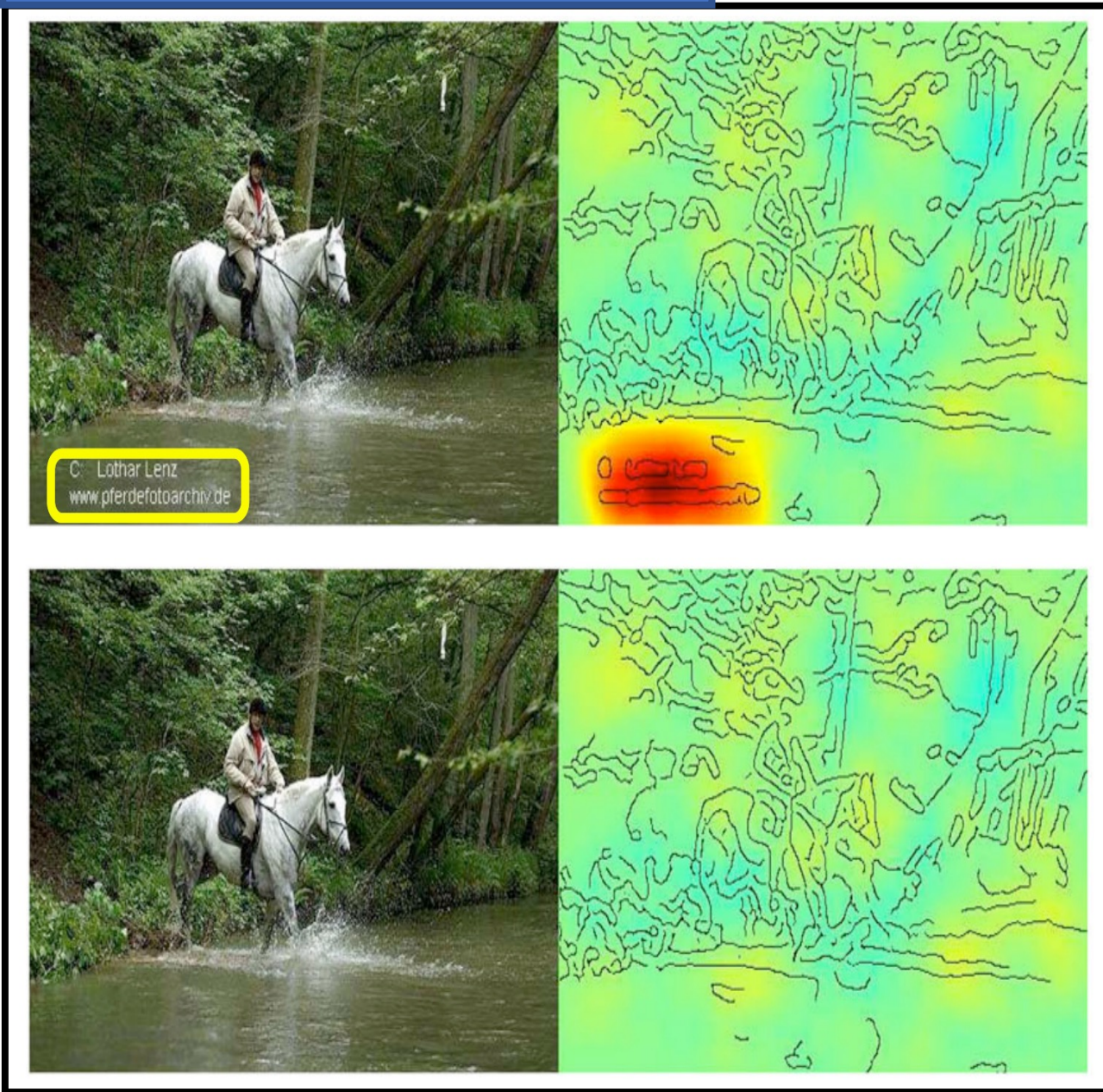


What can AI do?

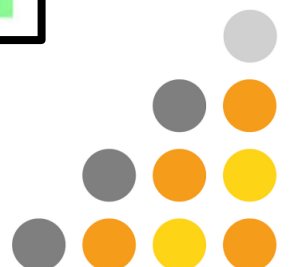
Clever Hans



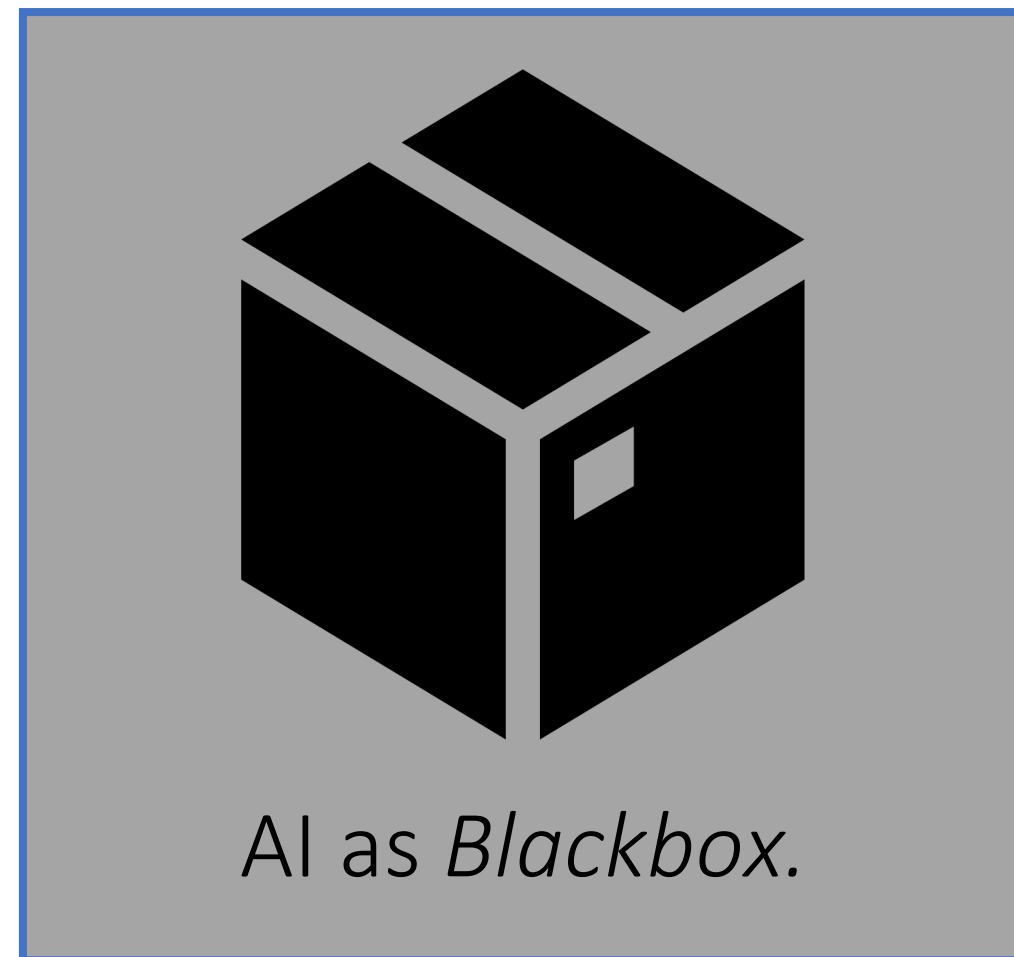
Clever Hans Effect



Recognition of an image based on its context

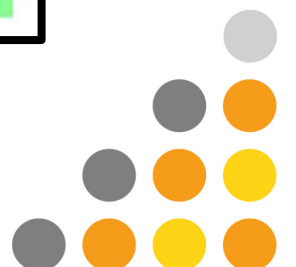
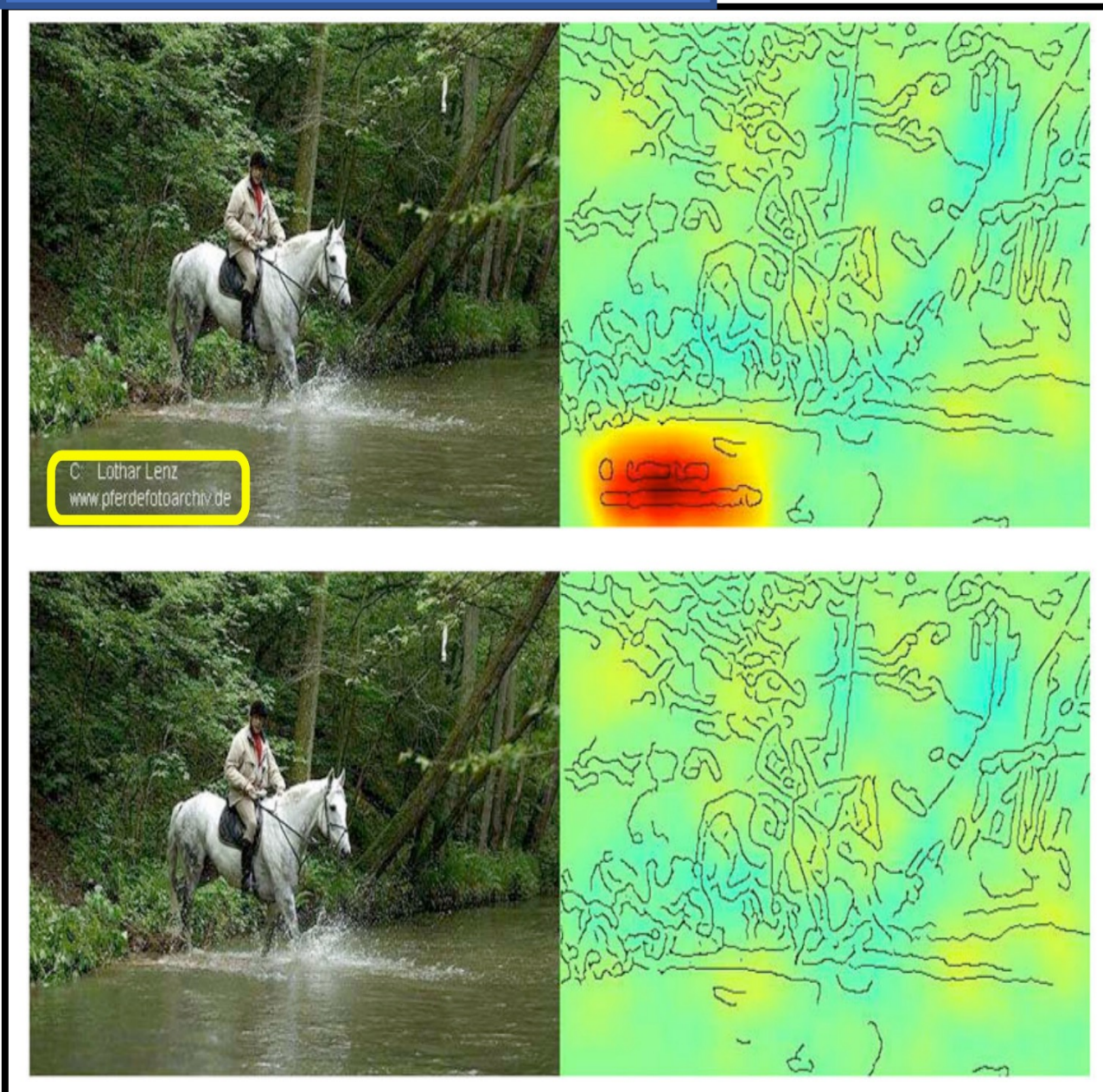


What can AI do?



- Thoroughly testing the function on external data is necessary

Clever Hans Effect

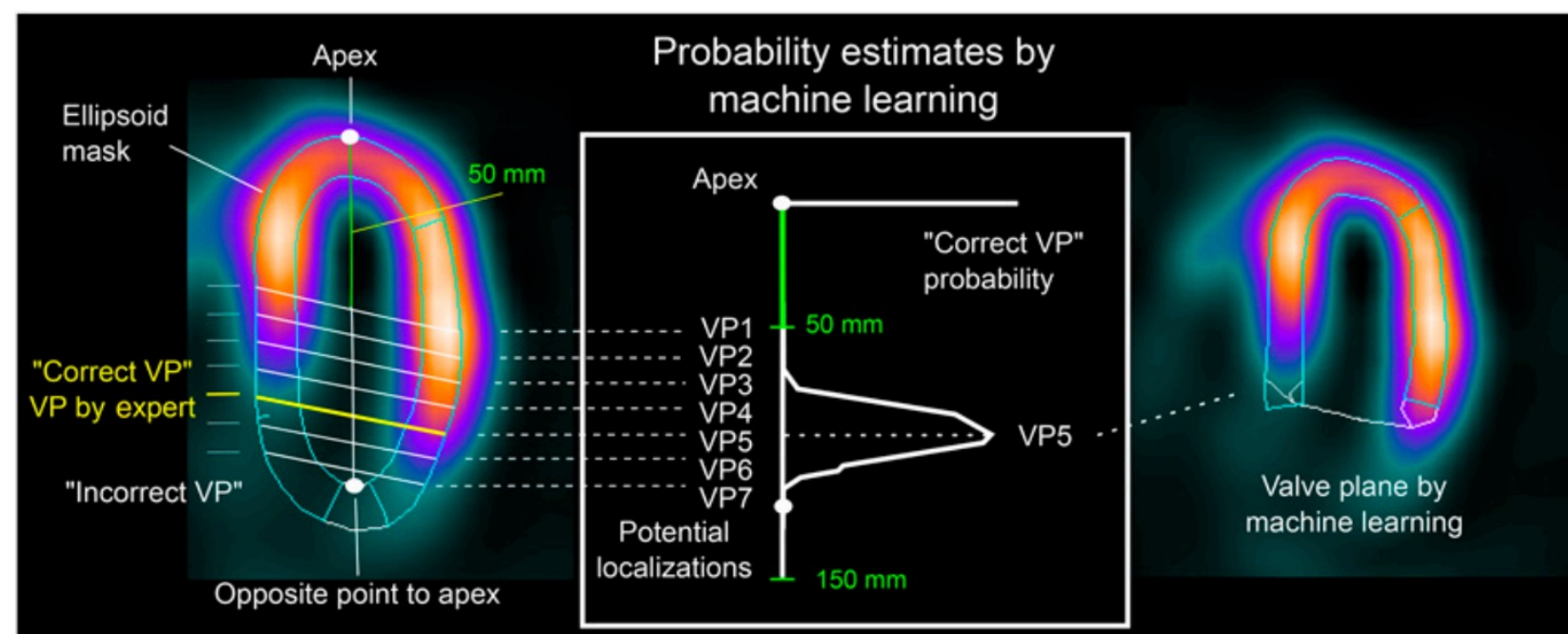


Technical simplifications & Workflow optimizations

Applications of AI in clinical nuclear medicine



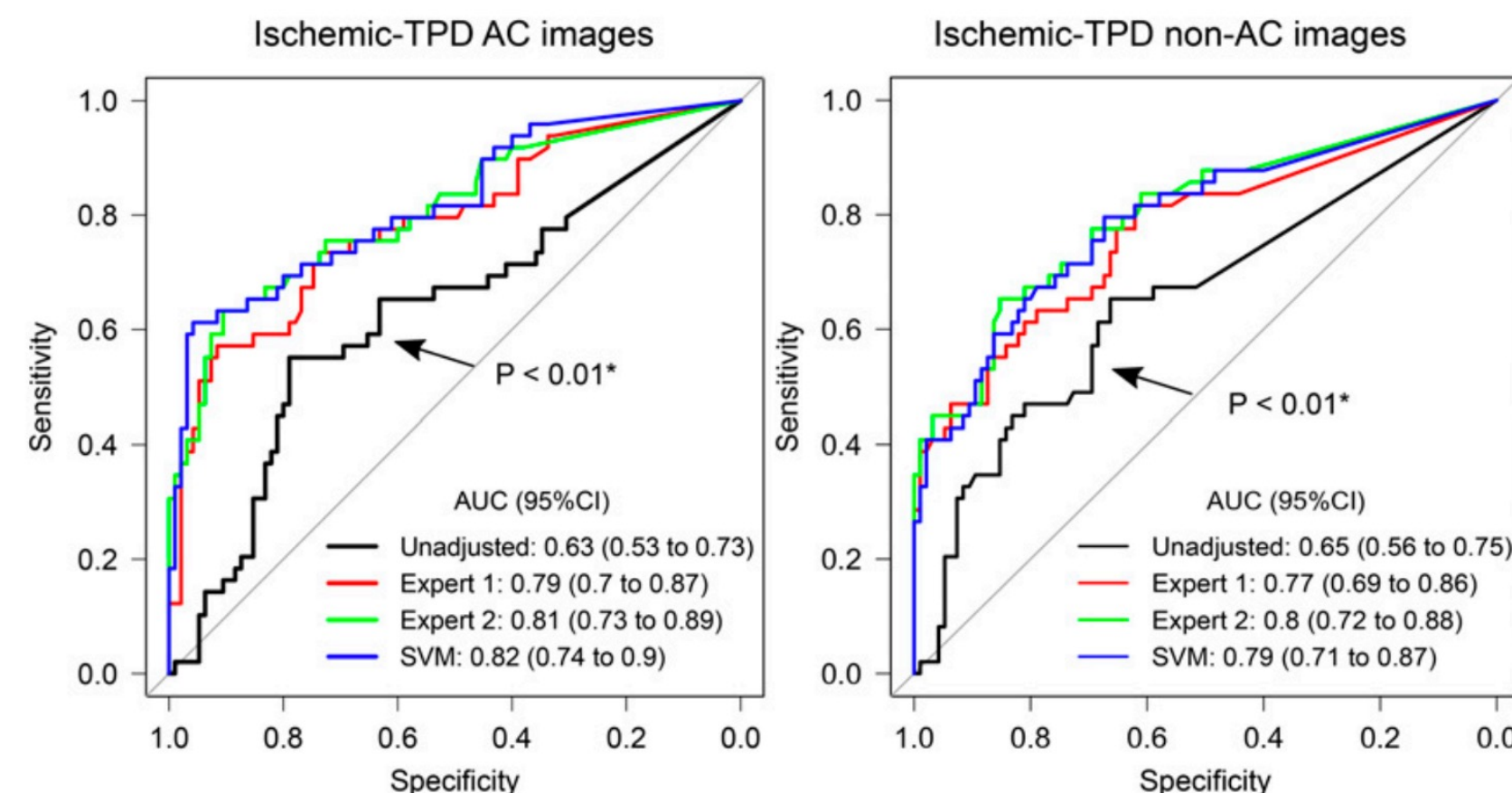
Workflow and Improvements



Machine Learning:
Support vector classification,
10-fold cross validation

392 patients

48 Patients with cardiac
catheterization



Betancur J et al. JNM 2017; 58:961-967



Attenuation Correction SPECT

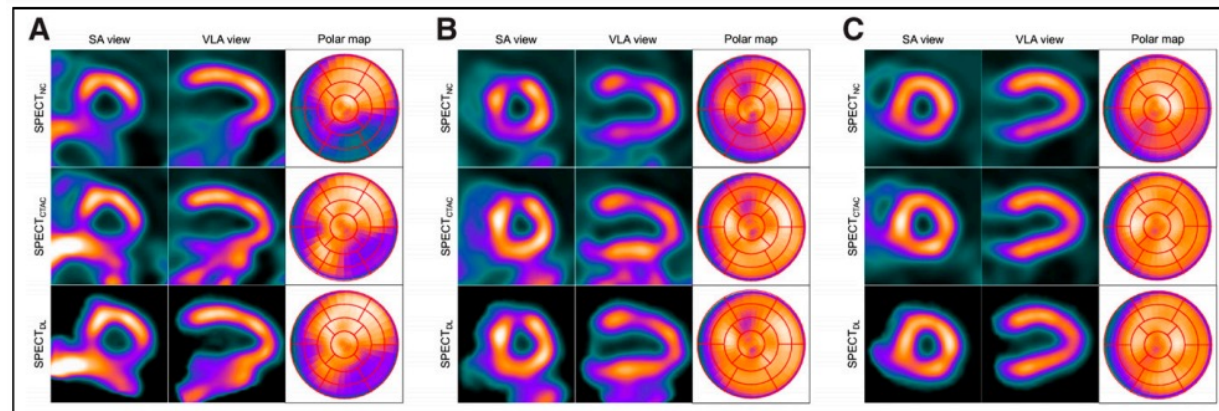


FIGURE 5. Examples of 3 subjects (A, male; B, male; C, male) with smallest absolute mean segmental error in short-axis (SA) and vertical long-axis (VLA) views and polar maps.

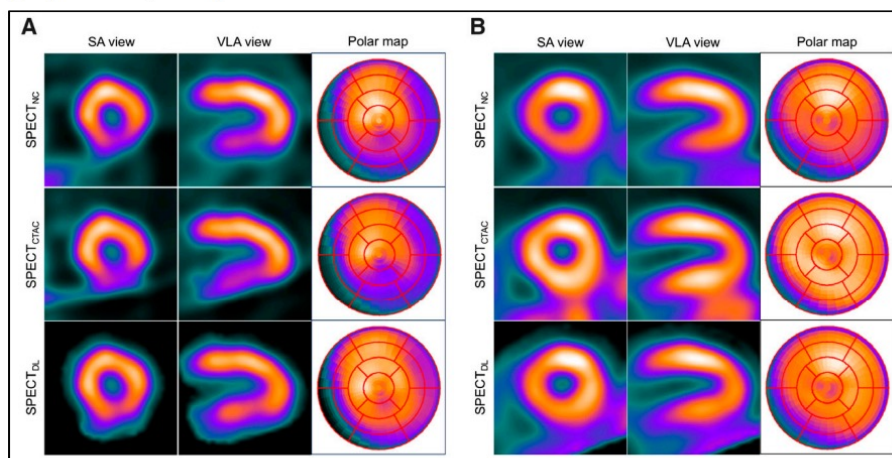


FIGURE 7. Examples of 2 subjects with most overestimated (A, male) and most underestimated (B, female) mean segmental errors in short-axis (SA) and vertical long-axis (VLA) views and polar maps.

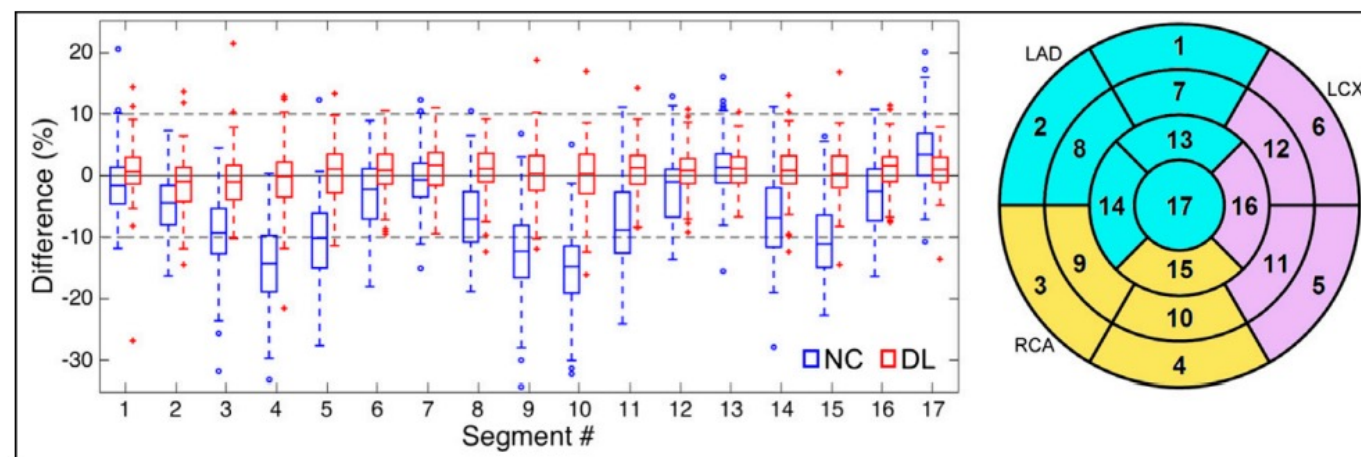
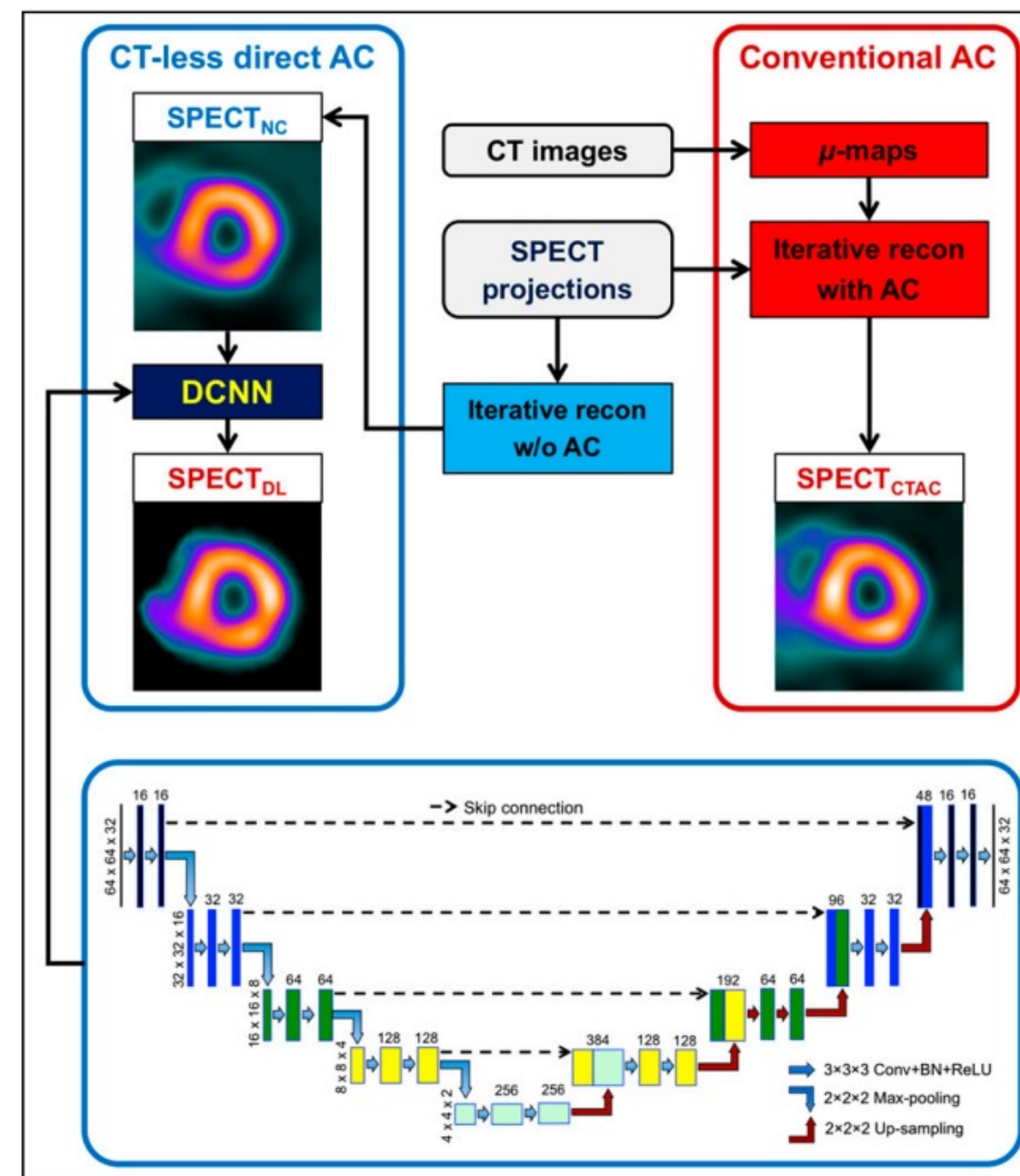


FIGURE 4. Polar map (right) and box plots (left) for percentage segmental errors across all subjects.

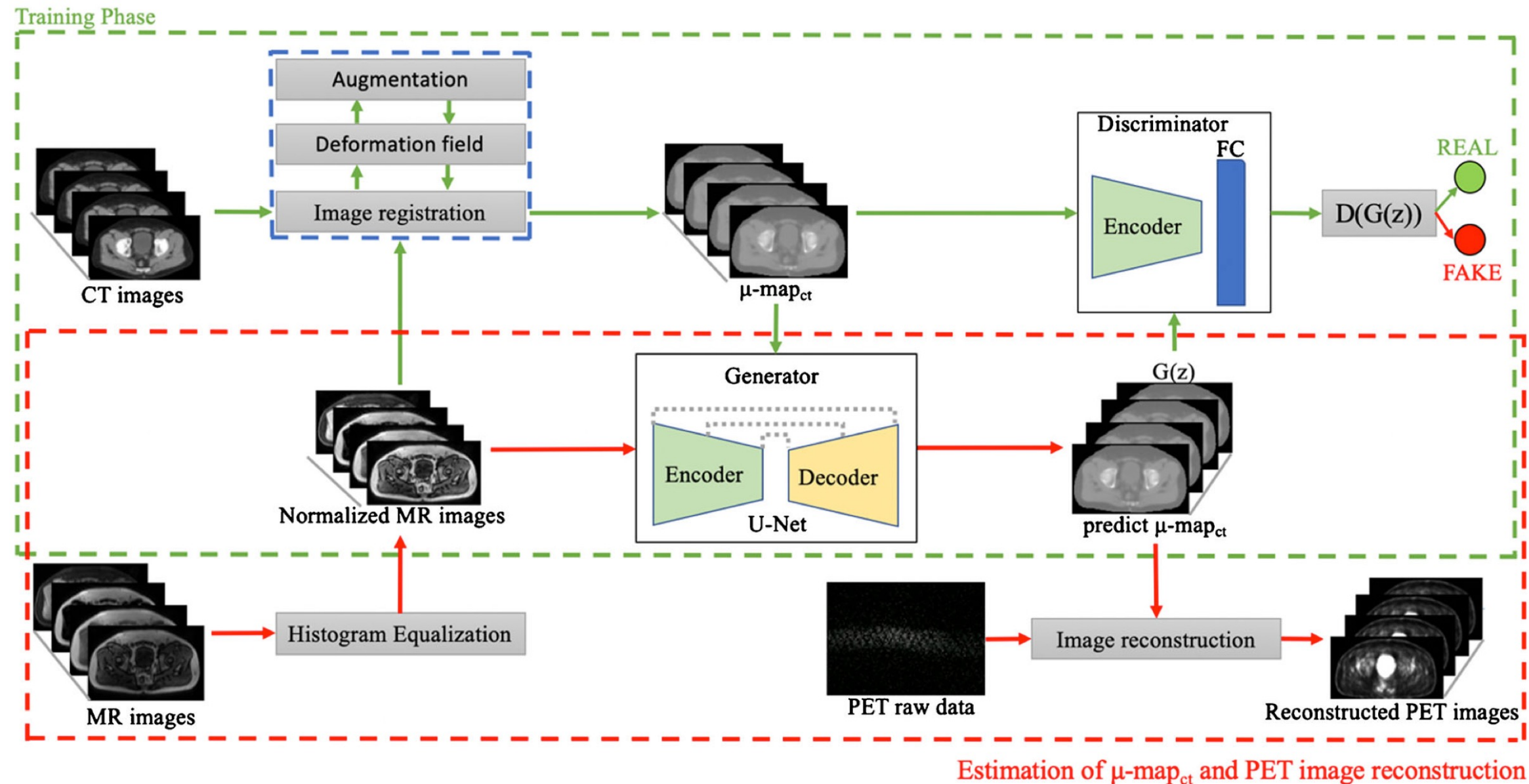


- 100 patients (58 male)
- stress-only Tc-99m tetrofosmin
- 10-fold cross validation without external validation

Yang J et al. JNM 2021; 62:1645-1652



Attenuation Correction PET

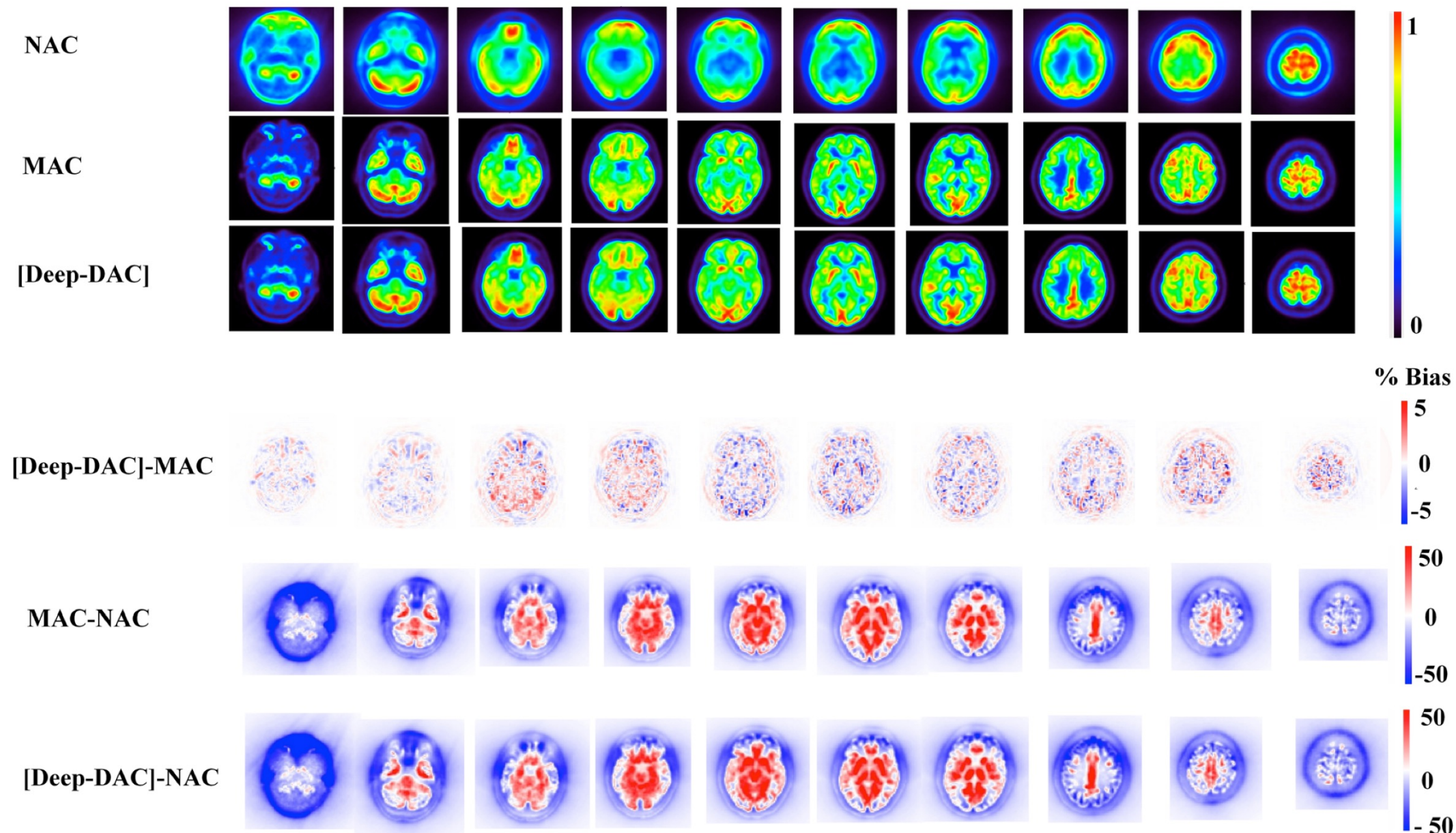


- Using MRI images for calculating attenuation correction maps
- MRI is used instead of CT scans
 - Significant improvement in image quality

Pozaruk, Andrii, et al. European journal of nuclear medicine and molecular imaging (2020): 1-12.



Attenuation Correction PET



- The PET images themselves are used for calculating attenuation correction maps
- No CT or MRI necessary

Shiri, Isaac, et al. European radiology 29.12 (2019): 6867-6879.



PET as fast as CT

European Journal of Nuclear Medicine and Molecular Imaging (2022) 49:4503–4515
<https://doi.org/10.1007/s00259-022-05901-x>

ORIGINAL ARTICLE

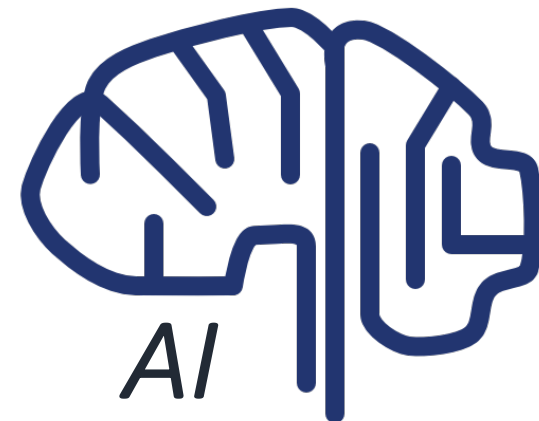


Artificial intelligence guided enhancement of digital PET: scans as fast as CT?

René Hosch^{1,2} · Manuel Weber³ · Miriam Sraieb³ · Nils Flaschel^{1,2} · Johannes Haubold¹ · Moon-Sung Kim^{1,2} · Lale Umutlu¹ · Jens Kleesiek² · Ken Herrmann³ · Felix Nensa^{1,2} · Christoph Rischpler³ · Sven Koitka^{1,2} · Robert Seifert^{3,4} · David Kersting³

20 seconds whole-body
PET acquisition

20 seconds PET



- Ultra-fast or ultra-low-dose
- More scans or less radiation exposure
- PET as a screening method

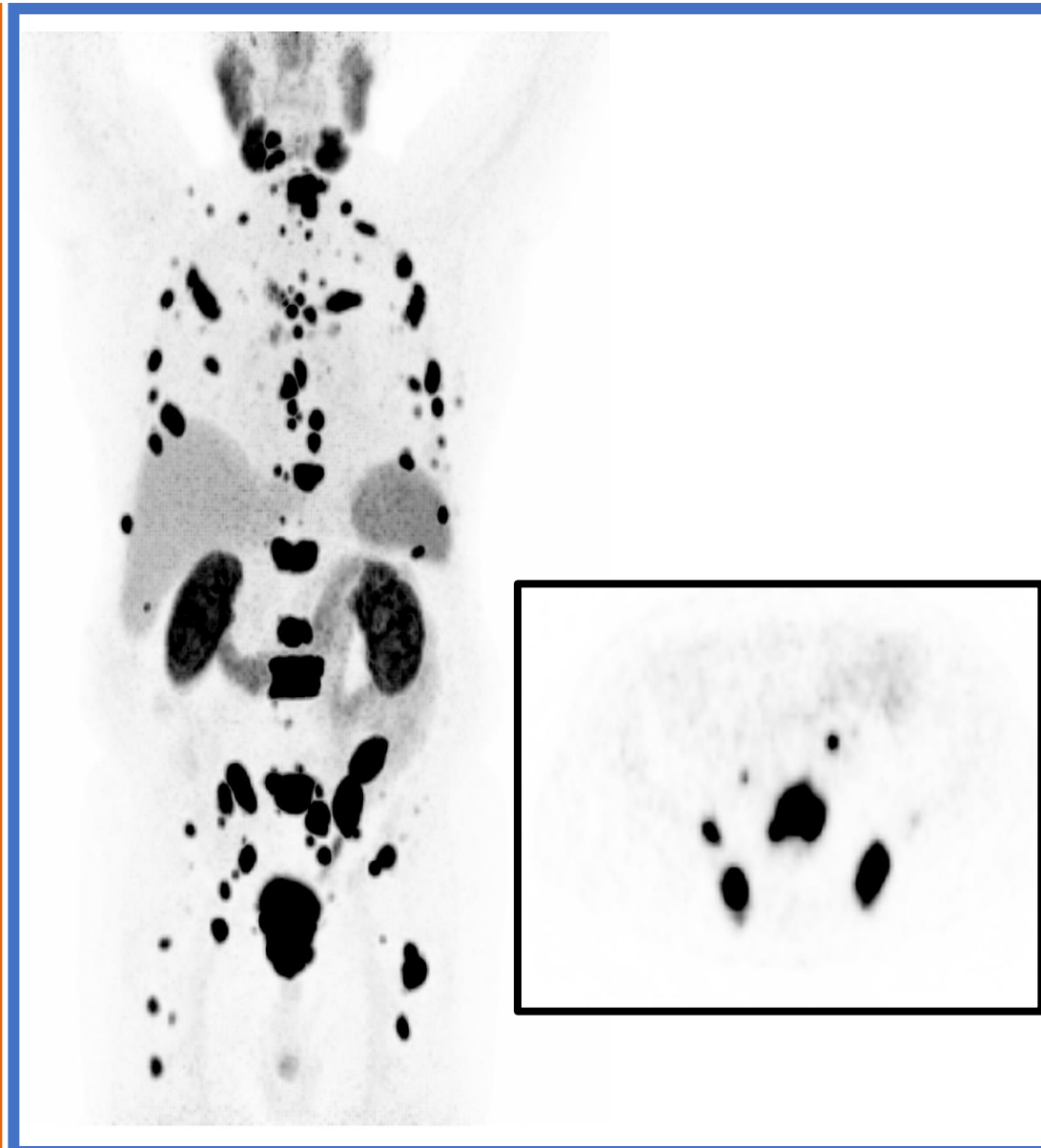
Enhanced PET



PET as fast as CT



Total acquisition 20 seconds



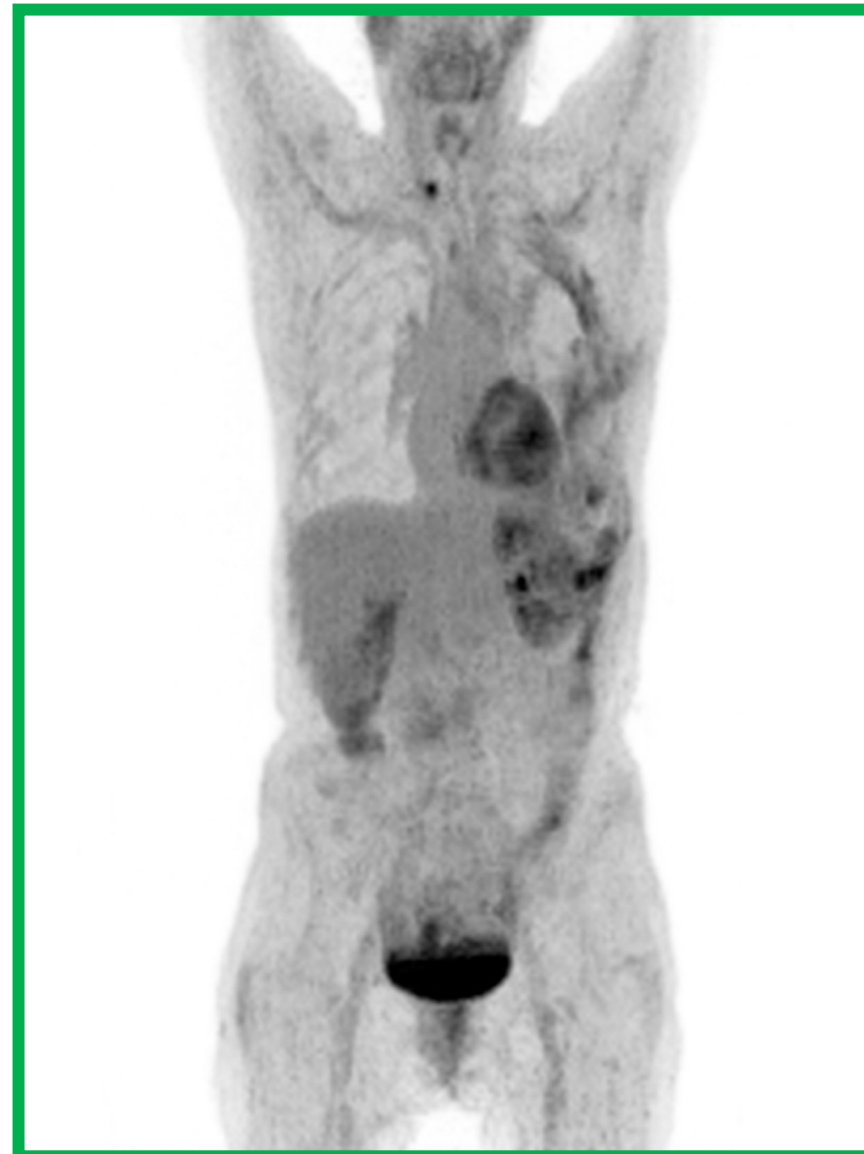
Total acquisition 15 minutes



PET as fast as CT



Ultra-fast PET



Synthetic PET



„Normal“ PET



Processing of whole-body data

Applications of AI in clinical nuclear medicine



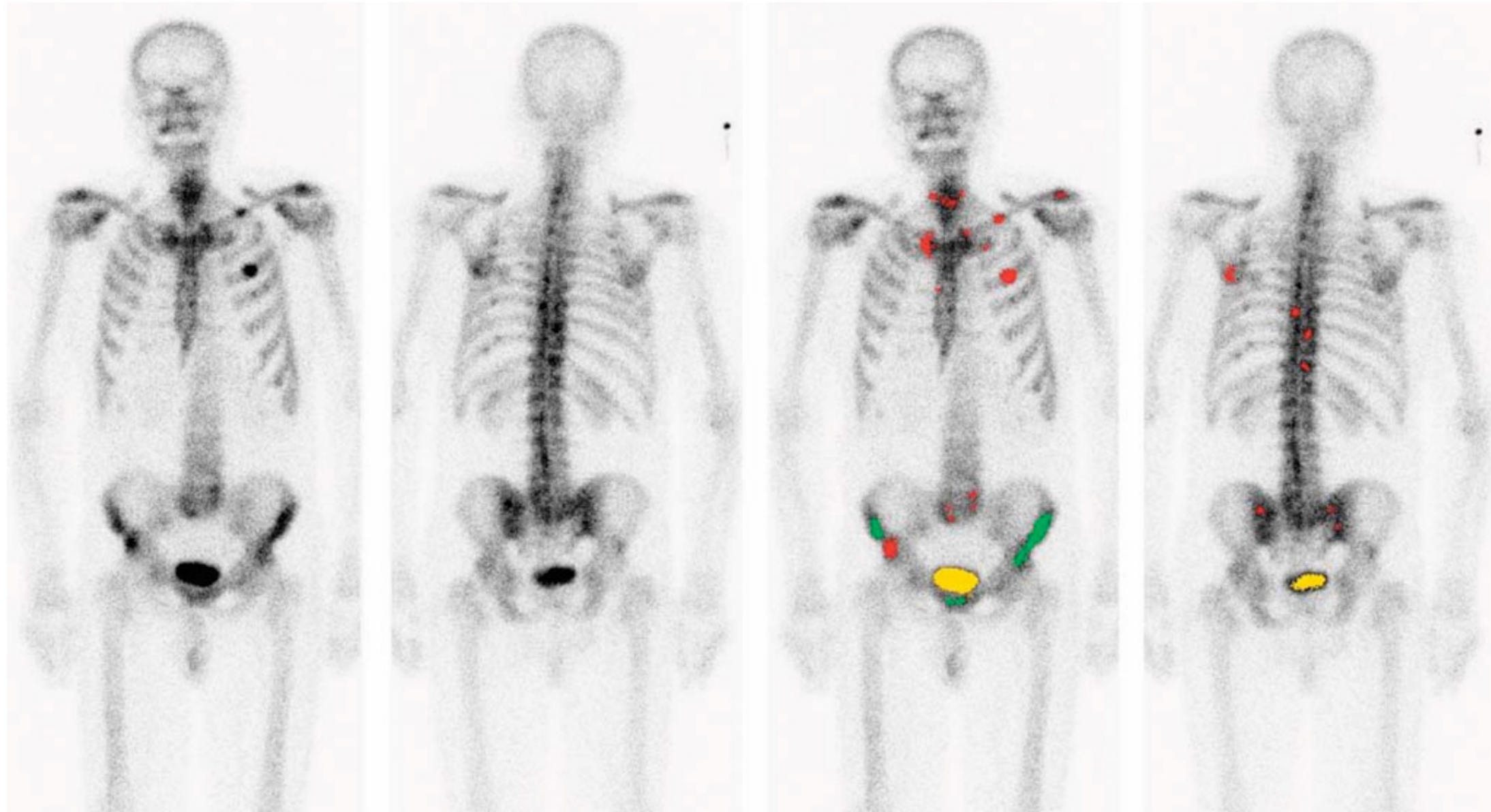
Tumor volume

Original article

A new computer-based decision-support system for the interpretation of bone scans

May Sadik^a, David Jakobsson^b, Fredrik Olofsson^b, Mattias Ohlsson^{b,c}, Madis Suurkula^a and Lars Edenbrandt^{a,b}

Nuclear
Medicine
Communications



- Automatic detection of bone metastases
- Determination of bone tumor volume
- Prognostic value that measures disease severity

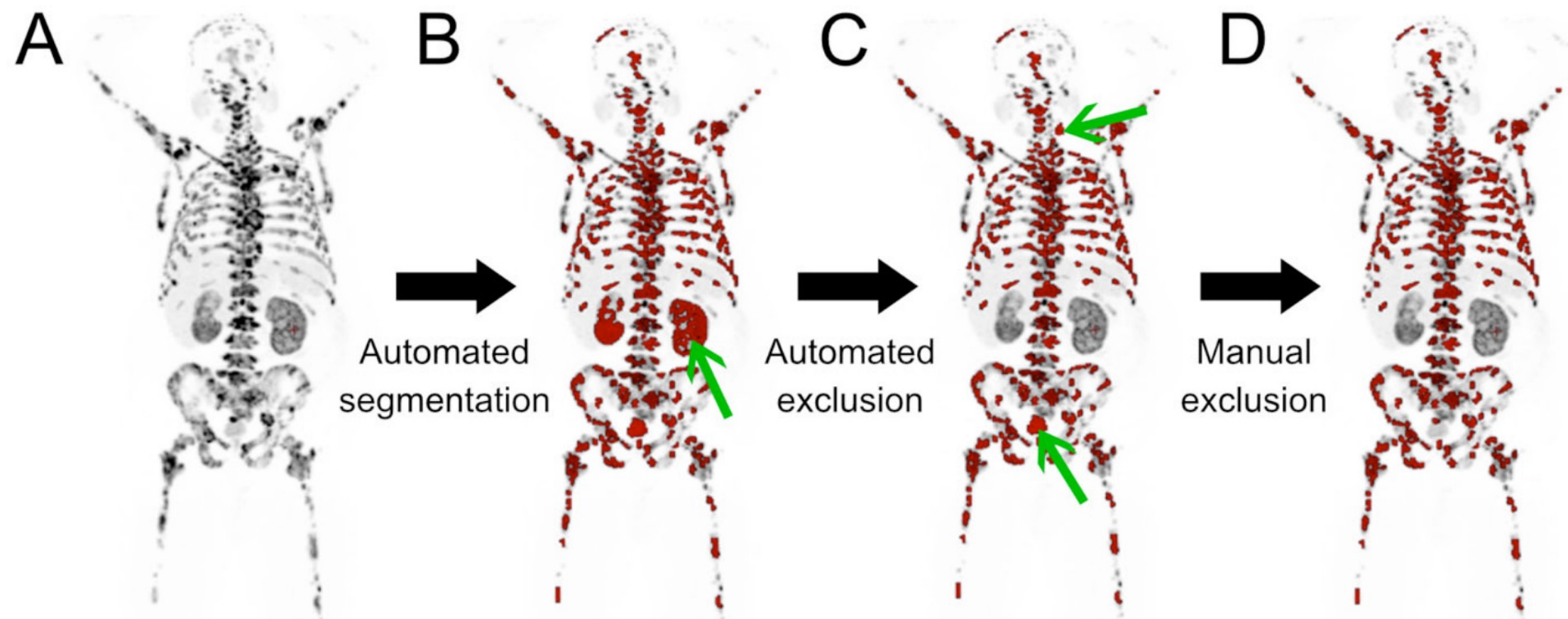
Sadik, May et al. "A new computer-based decision-support system for the interpretation of bone scans." Nuclear medicine communications vol. 27,5 (2006): 417-23. doi:10.1097/00006231-200605000-00002



Tumor volume

Semiautomatically Quantified Tumor Volume Using ^{68}Ga -PSMA-11 PET as a Biomarker for Survival in Patients with Advanced Prostate Cancer

Robert Seifert¹⁻⁴, Ken Herrmann²⁻⁴, Jens Kleesiek^{3,5}, Michael Schäfers^{1,4}, Vijay Shah⁶, Zhoubing Xu⁷, Guillaume Chabin⁷, Sasa Grbic⁷, Bruce Spottiswoode⁶, and Kambiz Rahbar^{1,4}



- Semi-automatic determination of tumor volume in PSMA PET scans
- Very precise assessment of disease severity
- Estimation of life expectancy

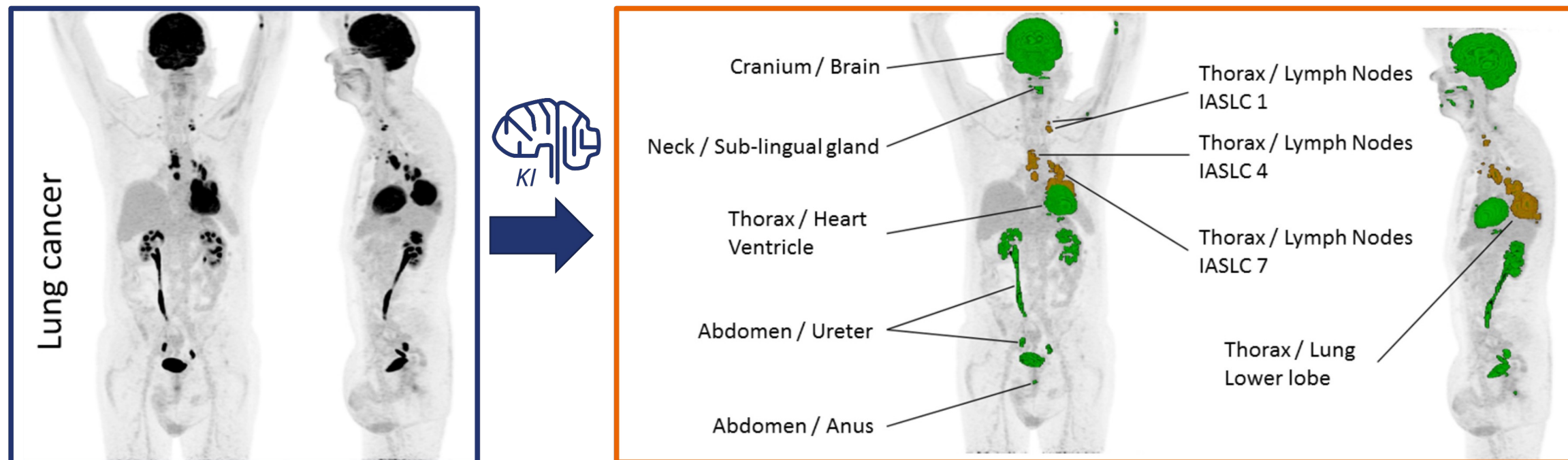
Seifert, Robert, et al. "Semiautomatically Quantified Tumor Volume Using ^{68}Ga -PSMA-11 PET as a Biomarker for Survival in Patients with Advanced Prostate Cancer." *Journal of Nuclear Medicine* 61.12 (2020): 1786-1792.



Automatic reporting

^{18}F -FDG PET/CT Uptake Classification in Lymphoma and Lung Cancer by Using Deep Convolutional Neural Networks

Ludovic Sibille, MS* • Robert Seifert, MD* • Nemanja Avramovic, MD • Thomas Vebren, MD • Bruce Spottiswoode, PhD • Sven Zuehlsdorff, PhD • Michael Schäfers, MD



- Fully automatic program for reading FDG PET scans.
- Detection of all metastases.
- Automatic indication of their location in the body

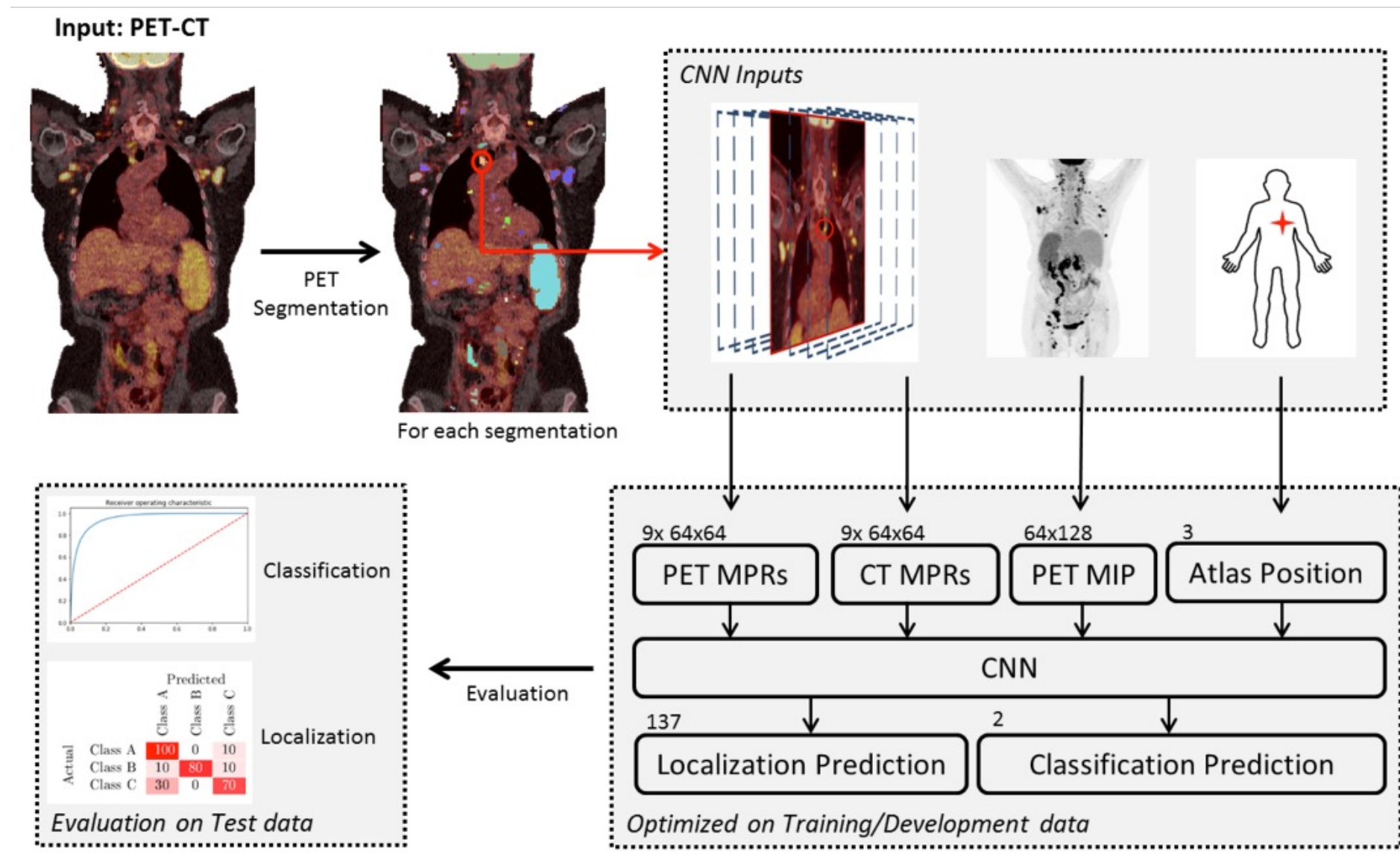
Sibille, Ludovic, et al. " ^{18}F -FDG PET/CT uptake classification in lymphoma and lung cancer by using deep convolutional neural networks." *Radiology* 294.2 (2020): 445-452.



Automatic reporting

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Sibille, Ludovic, et al. " ^{18}F -FDG PET/CT uptake classification in lymphoma and lung cancer by using deep convolutional neural networks." *Radiology* 294.2 (2020): 445-452.

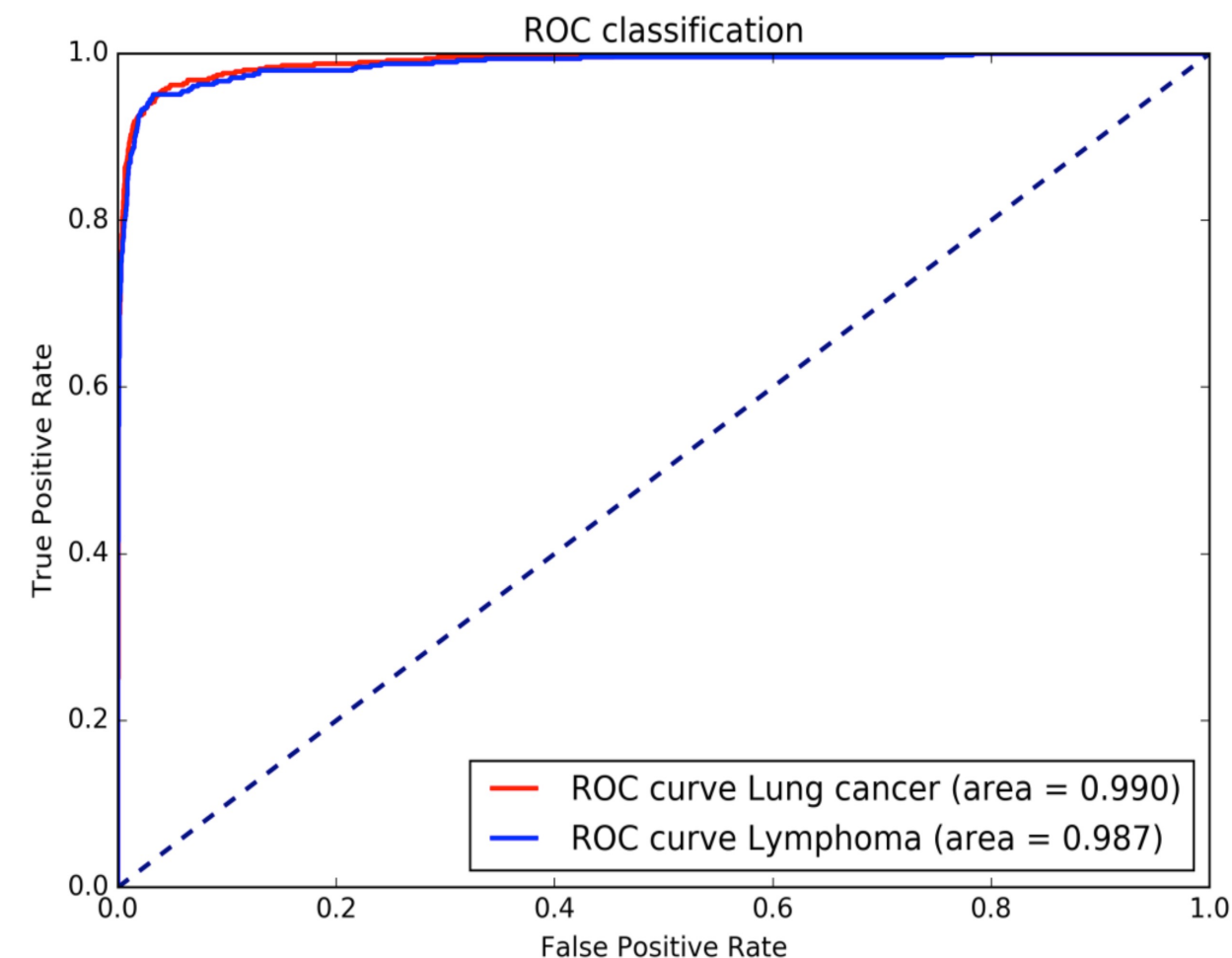


Automatic reporting

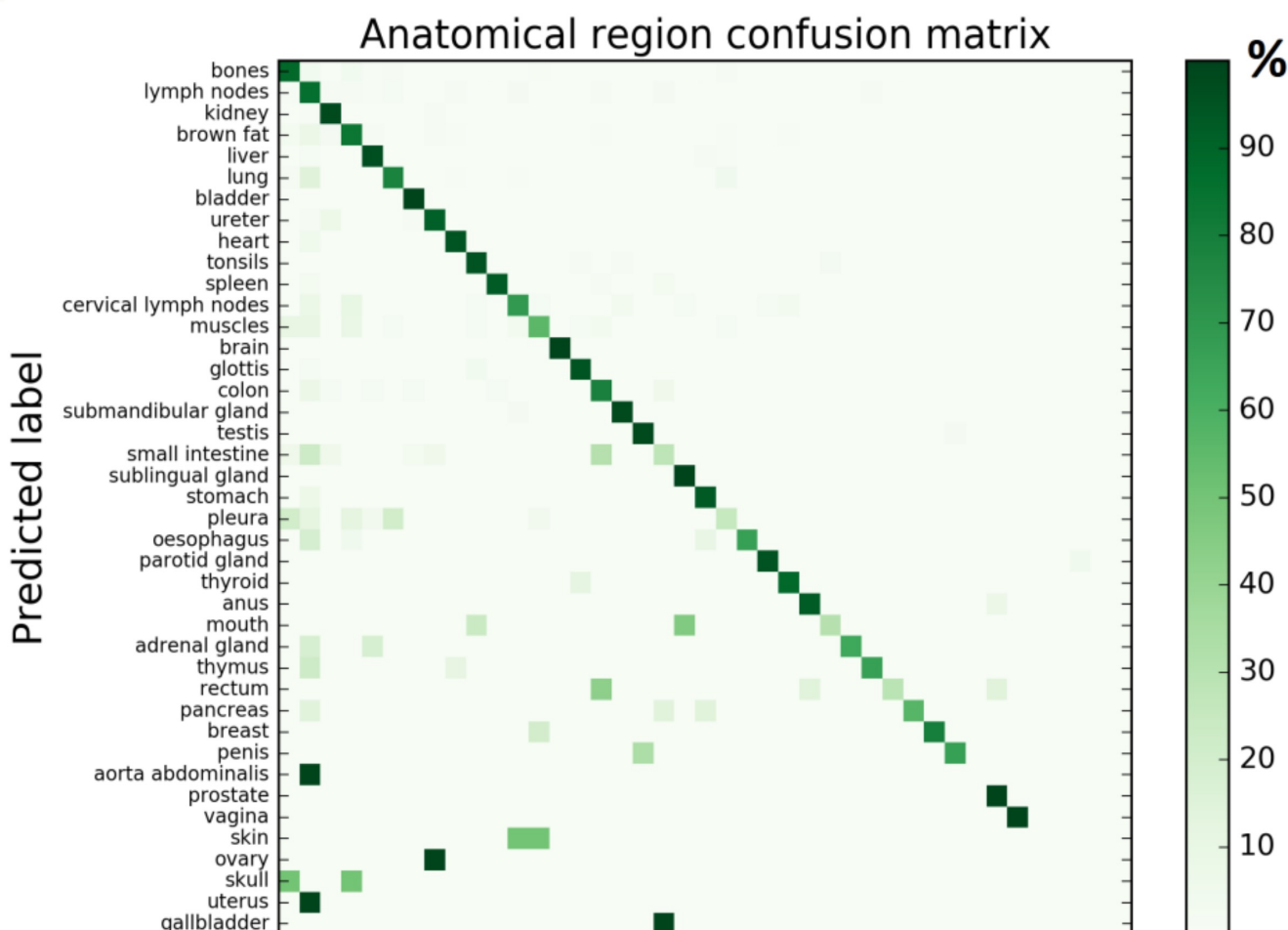
¹⁸F-FDG PET/CT Uptake Classification in Lymphoma and Lung Cancer by Using Deep Convolutional Neural Networks



Ludovic Sibille, MS* • Robert Seifert, MD* • Nemanja Avramovic, MD • Thomas Vebren, MD •
Bruce Spottiswoode, PhD • Sven Zuehlsdorff, PhD • Michael Schäfers, MD



Classification accuracy	Lung cancer (n=8,970)	Lymphoma (n=9,036)
Sensitivity	87.3%	85.1%
Specificity	99.2%	99.1%
Accuracy	98.5%	98.3%



Localization accuracy	Lung cancer (n=831)	Lymphoma (n=1,570)
Body part	96.9%	96.8%
Tissue/organ	88.0%	88.3%
Sub-region	82.6%	82.8%

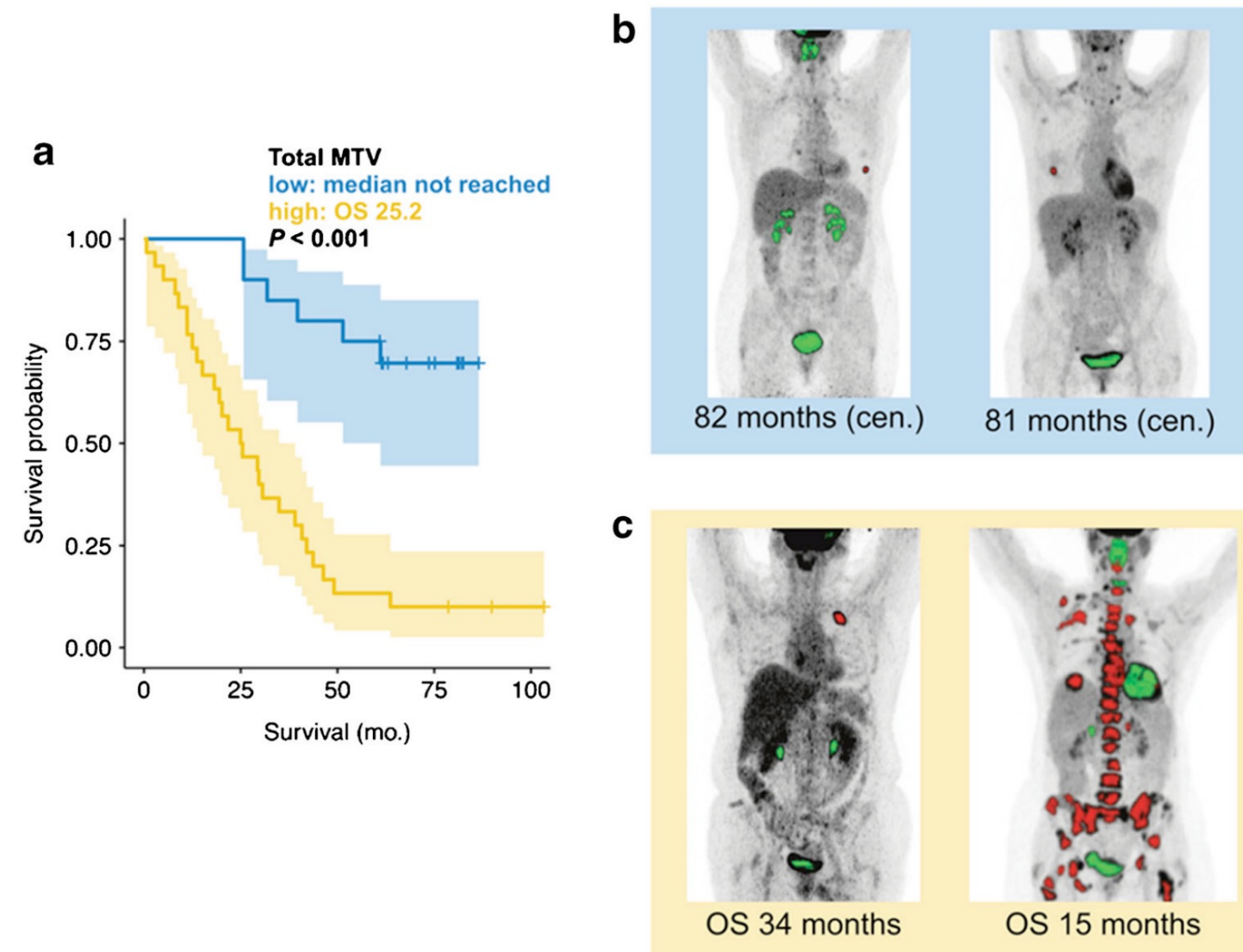
Sibille, Ludovic, et al. "18F-FDG PET/CT uptake classification in lymphoma and lung cancer by using deep convolutional neural networks." *Radiology* 294.2 (2020): 445-452.



Automatic reporting

Just another "Clever Hans"? Neural networks and FDG PET-CT to predict the outcome of patients with breast cancer

Manuel Weber^{1,2} • David Kersting^{1,2} • Lale Umutlu^{2,3} • Michael Schäfers^{2,5} • Christoph Rischpler^{1,2} • Wolfgang P. Fendler^{1,2} • Irène Buvat⁴ • Ken Herrmann^{1,2} • Robert Seifert^{1,2,5}



- Tumor volume has prognostic significance in many diseases.
- The neural network used is "generalizable".

Weber, Manuel, et al. "Just another "Clever Hans"? Neural networks and FDG PET-CT to predict the outcome of patients with breast cancer." European journal of nuclear medicine and molecular imaging (2021): 1-10.

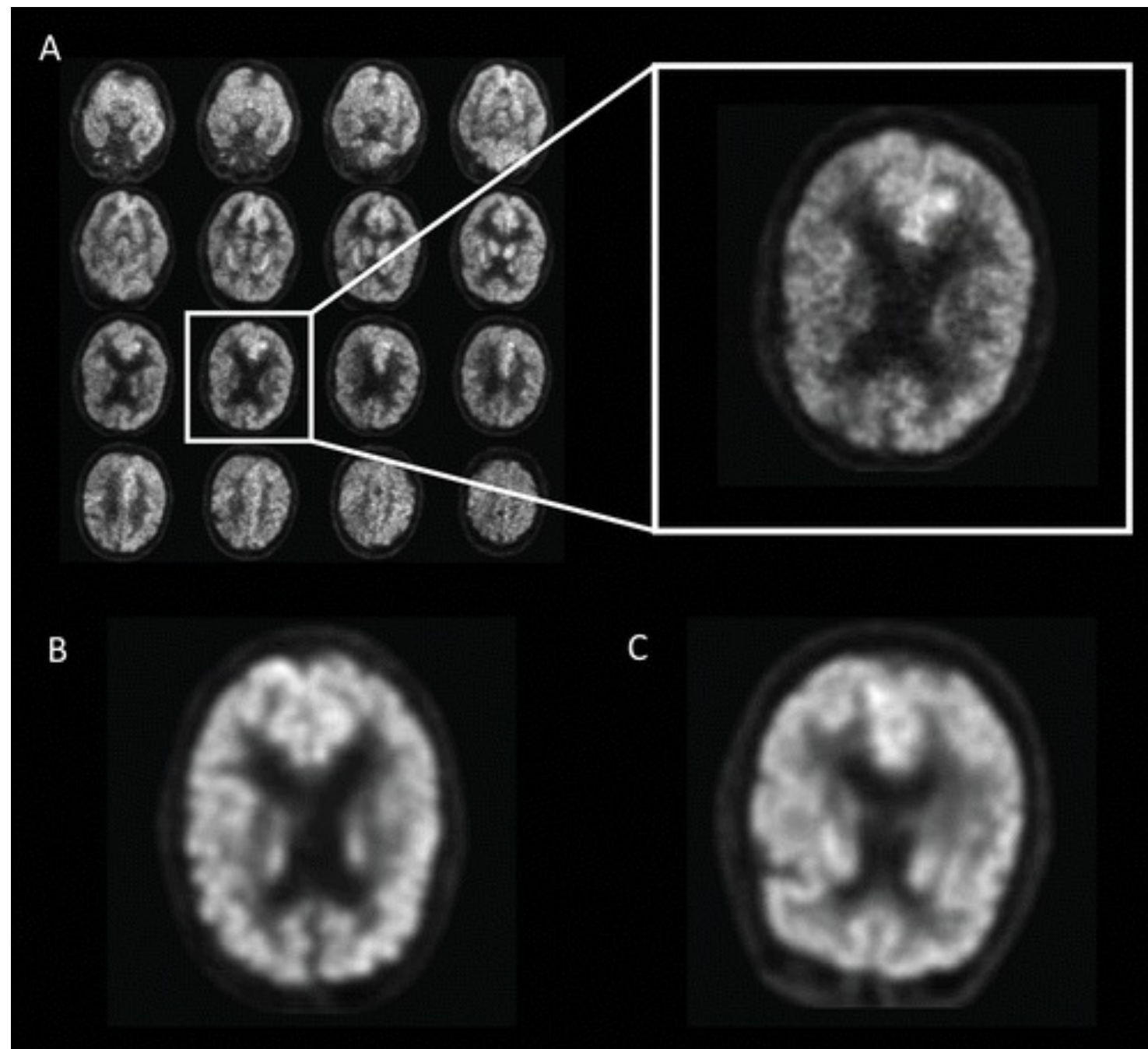


Processing of partial-body data

Applications of AI in clinical nuclear medicine



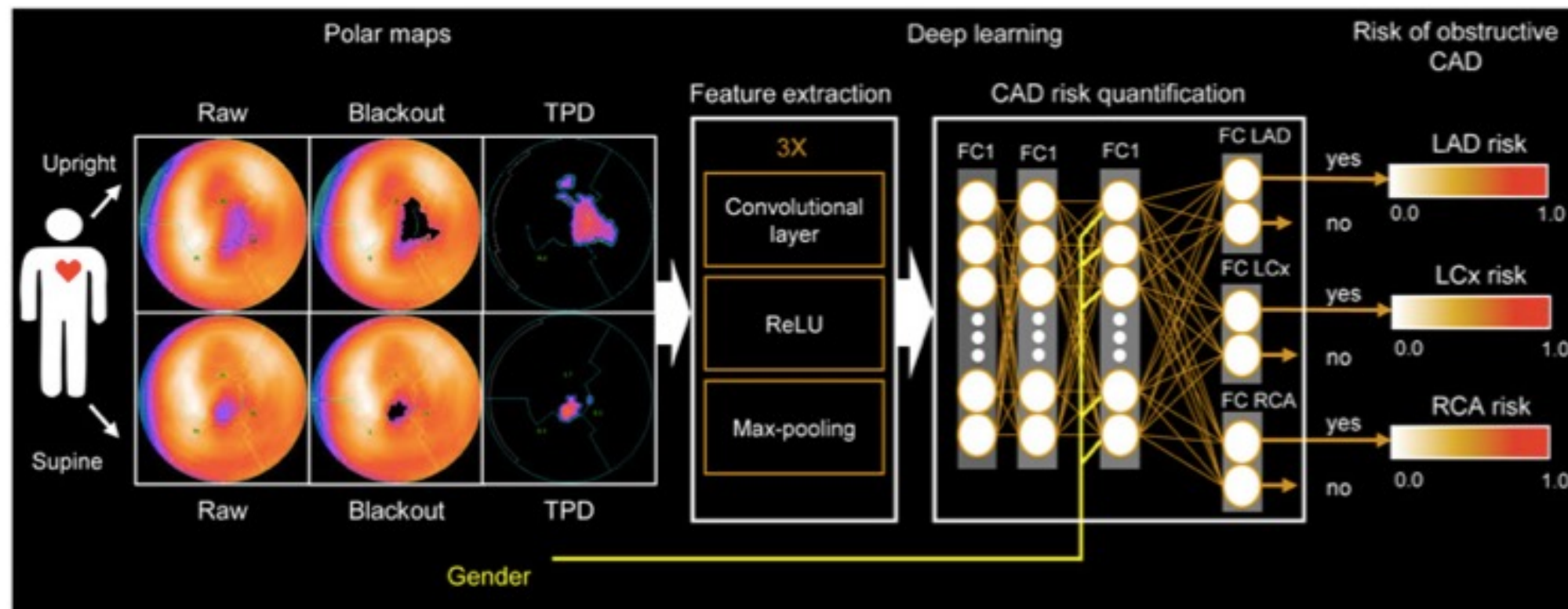
Prediction of Alzheimer's Disease



- Early detection of Alzheimer's disease only from FDG PET
- Prediction of Alzheimer's dementia diagnosis (100% sensitivity, 82% specificity)
- On average about 6 years before the final diagnosis
- Better than human evaluation (57% sensitivity, 91% specificity)



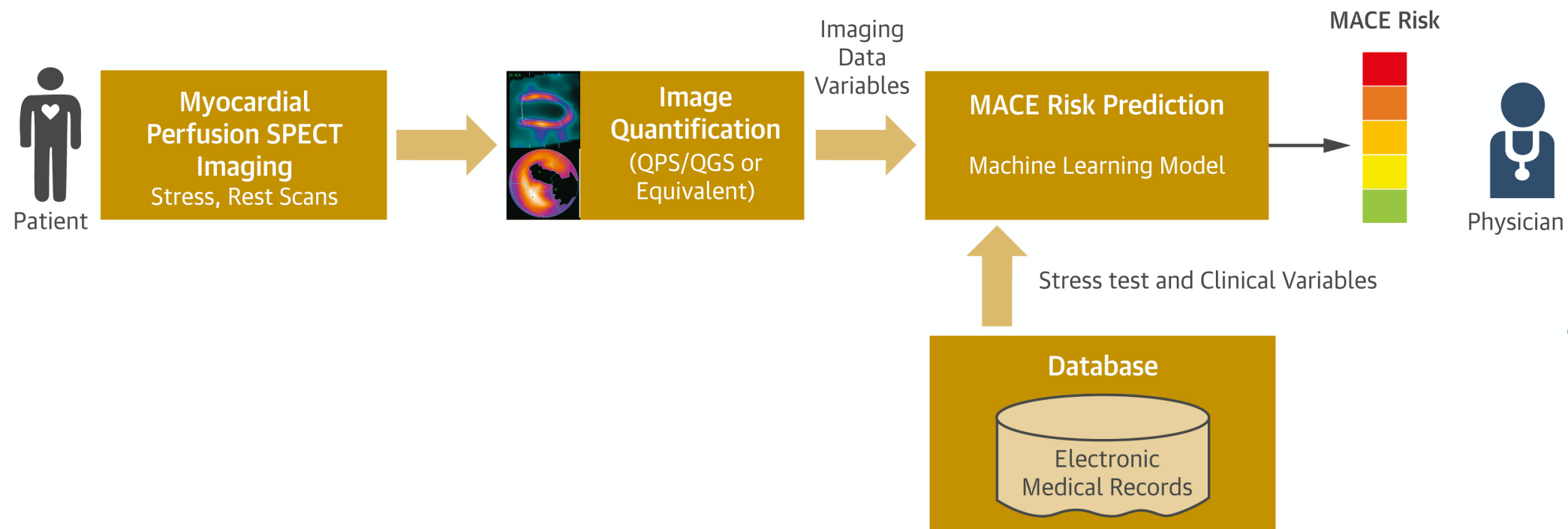
Evaluation of SPECT MPI



- Automatic evaluation of myocardial perfusion SPECT
- Evaluation of obstruction (overall and per vessel)
- Better than "standard" quantification methods



Prediction of cardiac events



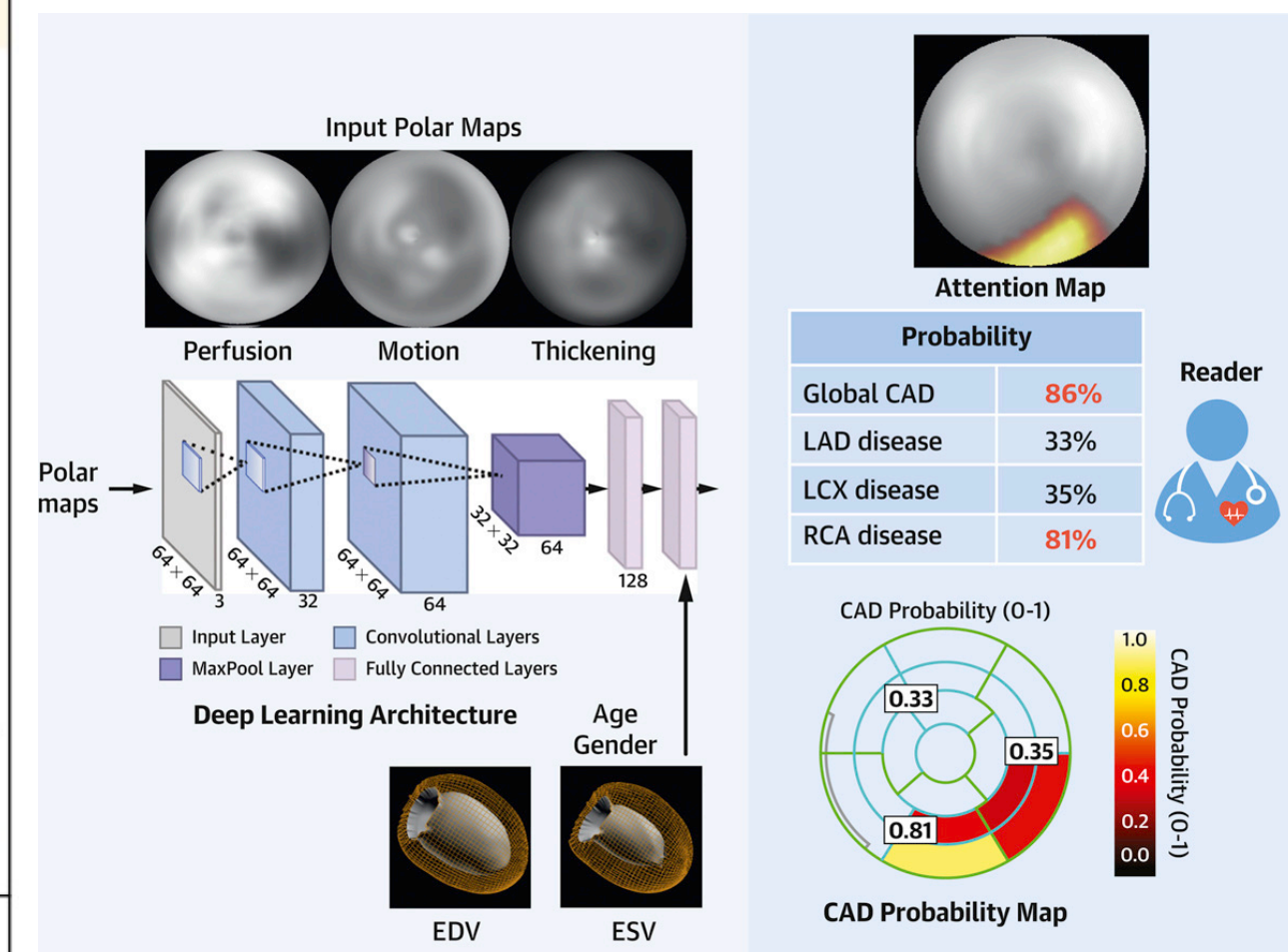
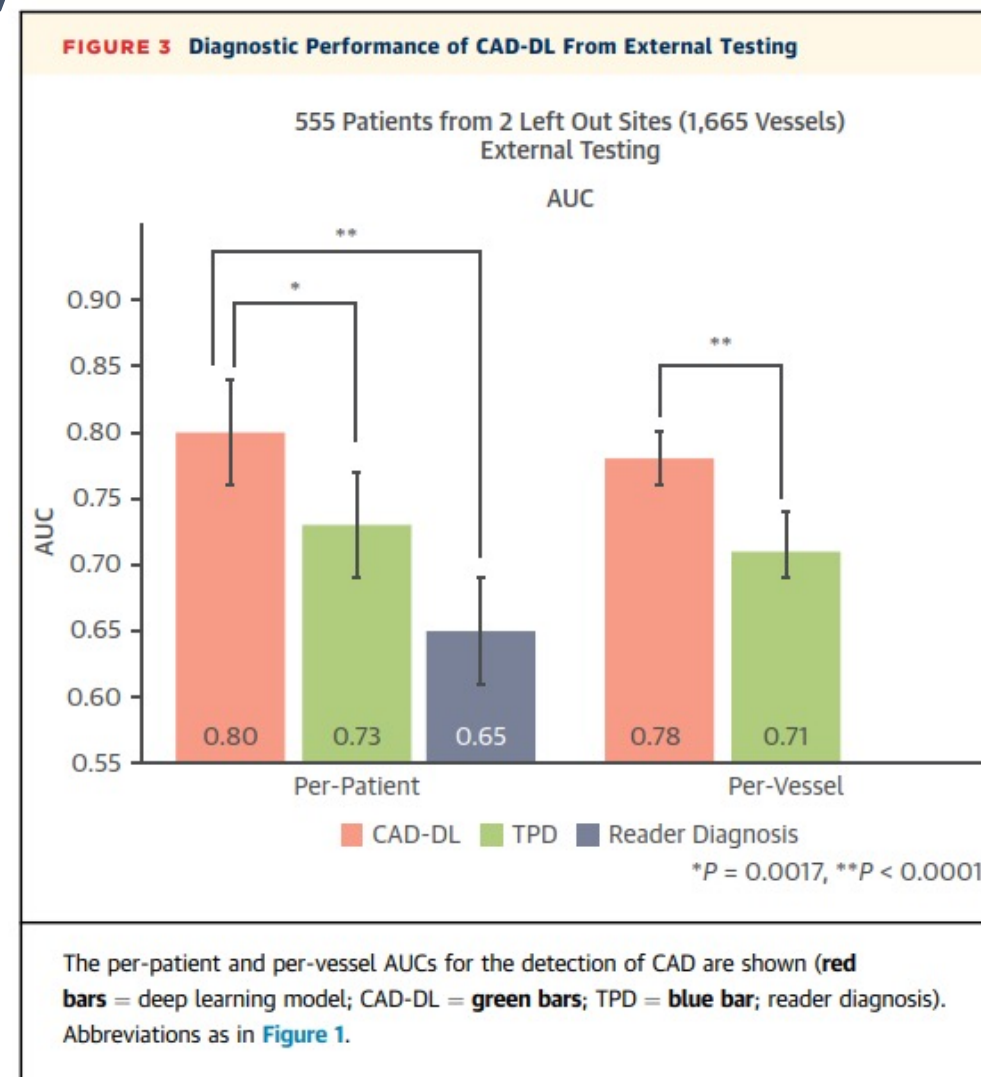
- Prediction of major adverse cardiac events in 3 years (heart attack, stroke, death from coronary heart disease)
- 2619 patients
- Machine learning + clinical information better than visual or automatic image analysis



Implementation into clinical routine

- 3,578 patients (10,734 coronary arteries) with suspected coronary artery disease
- SPECT myocardial perfusion scintigraphy
- Cardiac catheterization within 6 months (2,247 with obstructive coronary artery disease)
- 9 centers
- Additional 555 patients from 2 centers for external validation

- Clinical implementation (12 seconds)



Summary

Applications of AI in clinical nuclear medicine



Applications of AI in clinical nuclear medicine

- Simplifications and optimizations of image processing workflow
- Increase patient throughput
- Reduce administered activities

➤ PET as screening?

- Evaluation of complex (whole-body) parameters
- Fully automated evaluation/reporting of partial-body (and whole-body) data
- Prognostication of outcome parameters

➤ Valuable tools to be implemented into clinical routine applications



- Cartoon removed



- Cartoon removed



Thank you for the attention!



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