Department of Biomedical Imaging and Radiological Sciences, NYCU

Artificial Intelligence in Radiology
人工智慧於醫學影像應用

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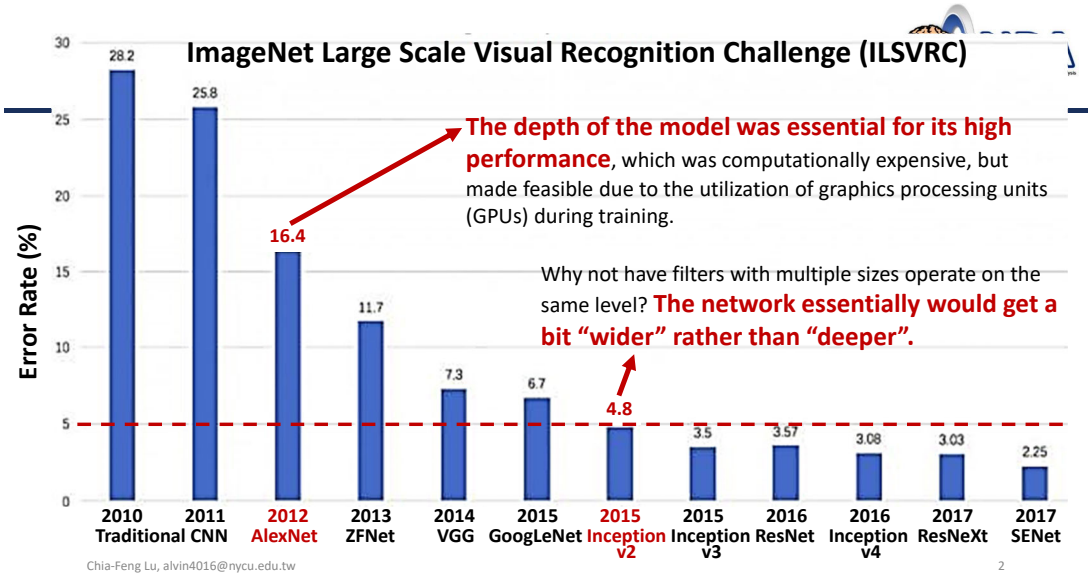
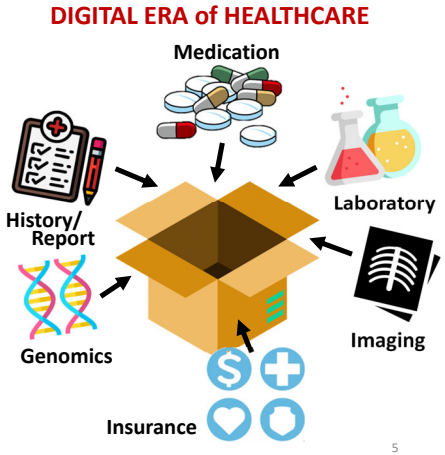
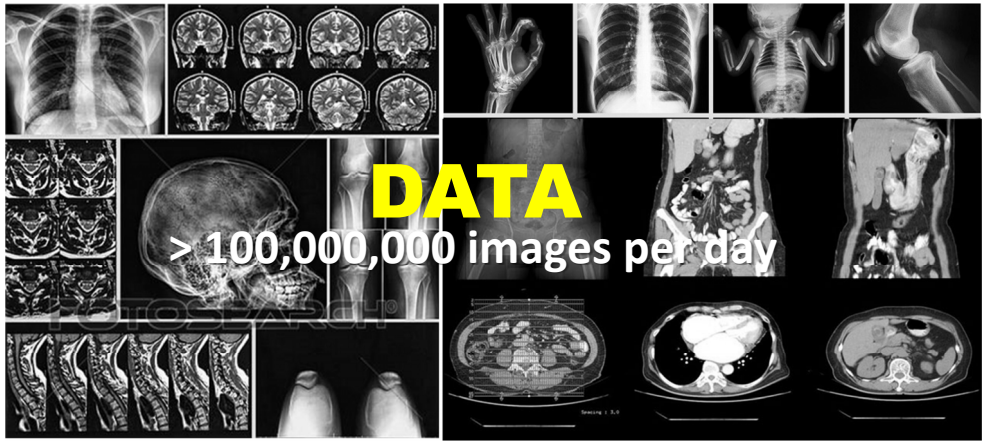


Information/Data Explosion

The Economist, May 2017.



Digital Medical Images



Three Phases of Scaling AI in Healthcare

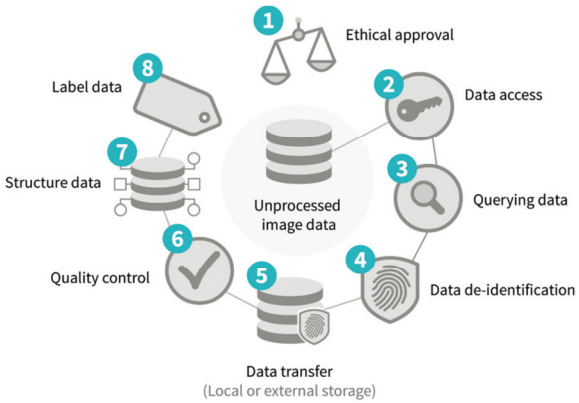
Phase 1
- **To address the routine, repetitive, and largely administrative tasks.**
- AI based on **imaging in radiology**, pathology, and ophthalmology.

Phase 2
- **To support the shift from hospital-based to home-based care.**
- Remote monitoring, AI-powered alerting systems or virtual assistants, as patients take increasing ownership of their care.

Phase 3
- **To improve clinical decision-support tools based on evidence from clinical trials.**
- AI as an integral part of the healthcare value chain.

Transforming healthcare with AI, March 2020, McKinsey & Company.

Collection of Medical Image Data



Protected Health Information

Identifier
Name
Address*
All elements (except years) of dates related to an individual†
Telephone numbers
Fax number
E-mail address
Social Security number
Medical record number
Health plan beneficiary number
Account number
Certificate or license number
Any vehicle or other device serial number
Device identifiers and serial numbers
Web URL
Internet Protocol (IP) address
Finger or voice print
Photographic image‡
Any other characteristic that could uniquely identify the individual

 Radiology. 295(1):4-15, 2020

Open-Source Medical Imaging Data Sets and Annotation (1/2)

Data Set Description	Image Types	No. of Patients	Ground Truth	Single or Multiple Institutions
American College of Radiology Imaging Network National CT Colonography Trial (ACRIN 6664) (102)	CT	825	Pathology (biopsies)	Multiple
Alzheimer's Disease Neuroimaging Initiative (103)	MRI, PET	>1700	Clinical (follow-up)	Multiple
Curated Breast Imaging Subset of the Digital Database for Screening Mammography (36)	Mammography	6671	Pathology (biopsies)	Multiple
ChestX-ray8, National Institutes of Health chest x-ray database (41)	Radiography	30 805	Imaging reports	Single
CheXpert, chest radiographs (79)	Radiography	65 240	Imaging reports	Single
Collaborative Informatics and Neuroimaging Suite (104)	MRI		Clinical (follow-up)	Multiple
DeepLesion, body CT (60)	CT	4427	Imaging	Single
Head and neck PET/CT (105)	PET/CT, CT	298	Pathology (biopsies), clinical (follow-up)	Multiple

 Radiology. 295(1):4-15, 2020

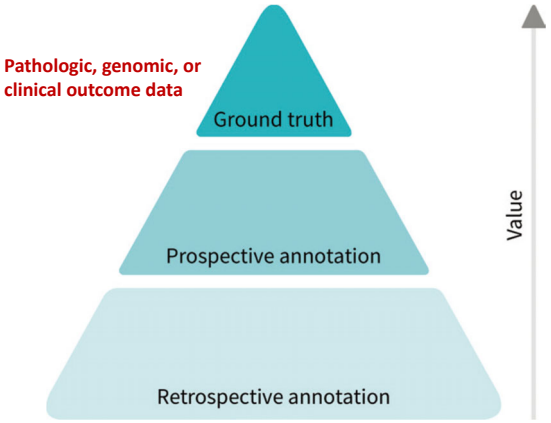
Open-Source Medical Imaging Data Sets and Annotation (2/2)

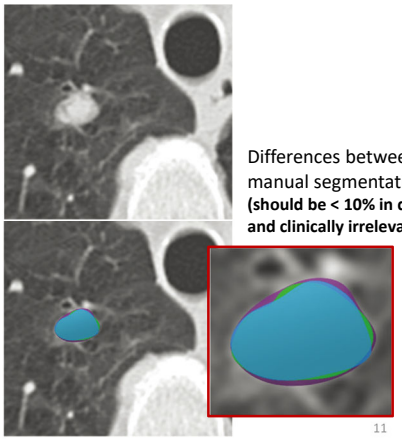
Data Set Description	Image Types	No. of Patients	Ground Truth	Single or Multiple Institutions
Lung Image Database Consortium image collection (106)	CT, radiography	1010	Imaging, clinical for a subset	Multiple
MRNet, knee MRI (80)	MRI	1370	Imaging reports	Single
Musculoskeletal bone radiographs, or MURA (107)	Radiography	14 863	Imaging reports	Single
National Lung Screening Trial (108)	CT, pathology	26 254	Clinical (follow-up)	Multiple
PROSTATEx Challenge, SPIE-AAPM-NCI Prostate MR Classification Challenge (109)	MRI	346	Pathology (biopsies), imaging	Multiple
Radiological Society of North America Intracranial Hemorrhage Detection (110)	CT	25 000	Imaging	Multiple
Cancer Genome Atlas Kidney Renal Clear Cell Carcinoma data collection (111)	CT, MRI	267	Pathology (biopsies), clinical (follow-up)	Multiple
Virtual Imaging Clinical Trial for Regulatory Evaluation (112)	Mammography, digital breast tomosynthesis	2994	Imaging	Multiple

Note.—AAPM = American Association of Physicists in Medicine, NCI = National Cancer Institute, SPIE = Society of Photo-Optical Instrumentation Engineers.

 Radiology. 295(1):4-15, 2020

Imaging Annotation

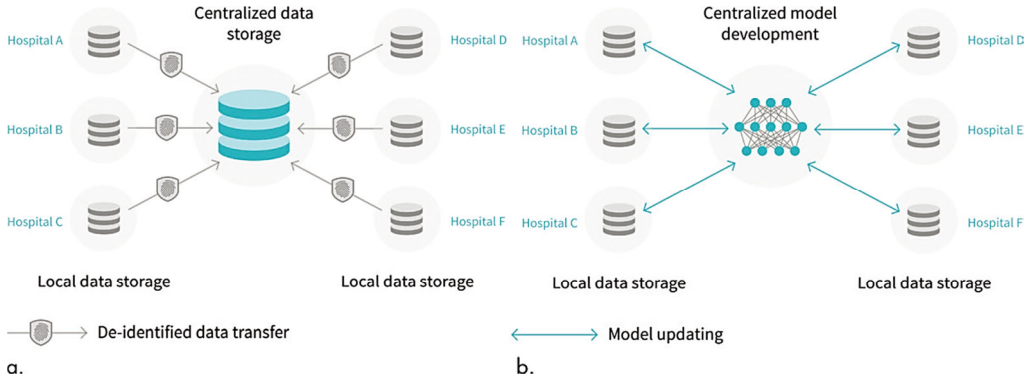




Differences between manual segmentations. **(should be < 10% in diff. and clinically irrelevant)**

Radiology. 295(1):4-15, 2020

Centralized vs. Federated Learning



Radiology. 295(1):4-15, 2020

Benefit of AI in Medical imaging

- 優化檢查流程 Workflow optimization ⇔ maximize the value of healthcare

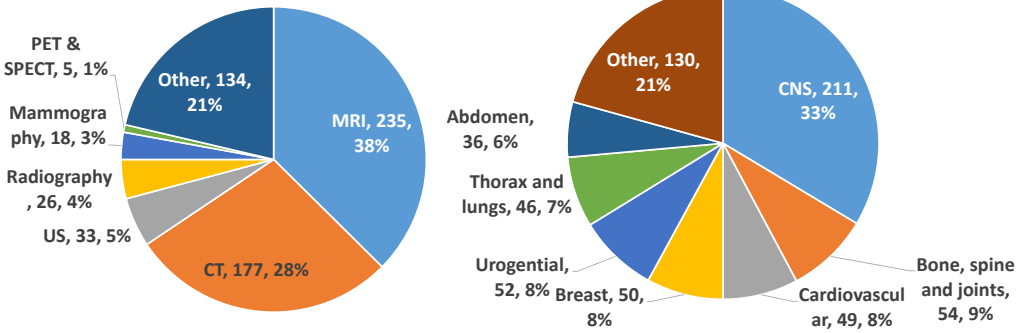
- 影像擷取 Image acquisition ⇔ short acquisition time, denoise, lower dose
- 病灶偵測 Lesion detection ⇔ unload radiologist's work, early/tiny sign
- 鑑別診斷 Differential diagnosis ⇔ urgent/non-urgent, disease screening

- 疾病分級 Disease grading
- 基因預測 Genotypes prediction
- 預後預測 Prognosis prediction

⇔ treatment strategy, survival prediction

Radiology Again at The Forefront of Innovation in Medicine

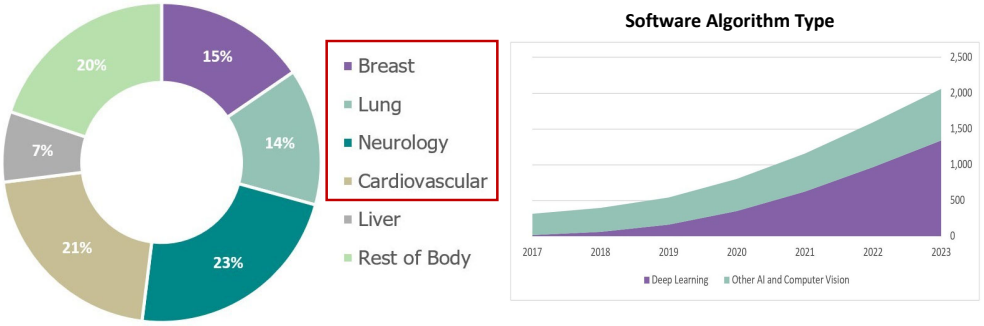
- Over 10 years, publications on AI in Radiology have increased from 100–150 per year to 700–800 per year.



Pesapane et al. European Radiology Experimental (2018) 2:35

World Market for AI-Based Medical Image Analysis Software in 2023

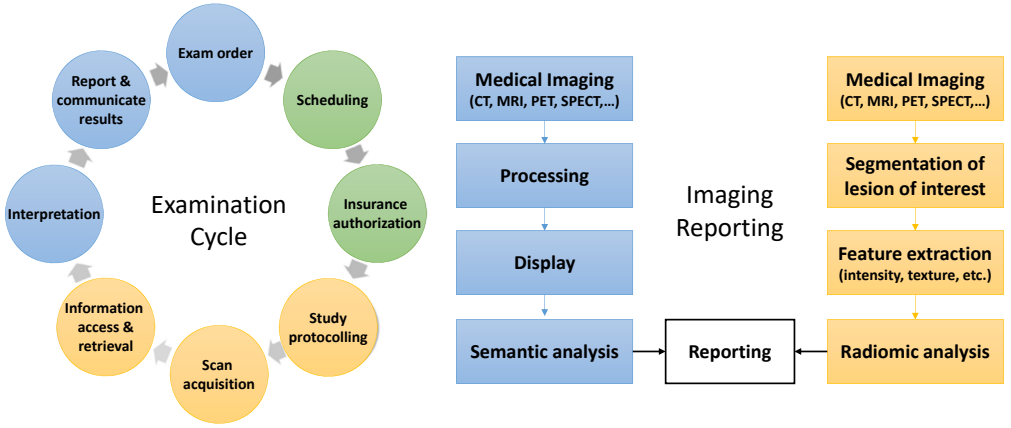
- AI in Medical Imaging to Top $2 Billion by 2023.



Signify Research, Aug 02, 2018.
https://www.prnewswire.com/news-releases/ai-in-medical-imaging-to-top-2-billion-by-2023-300691229.html

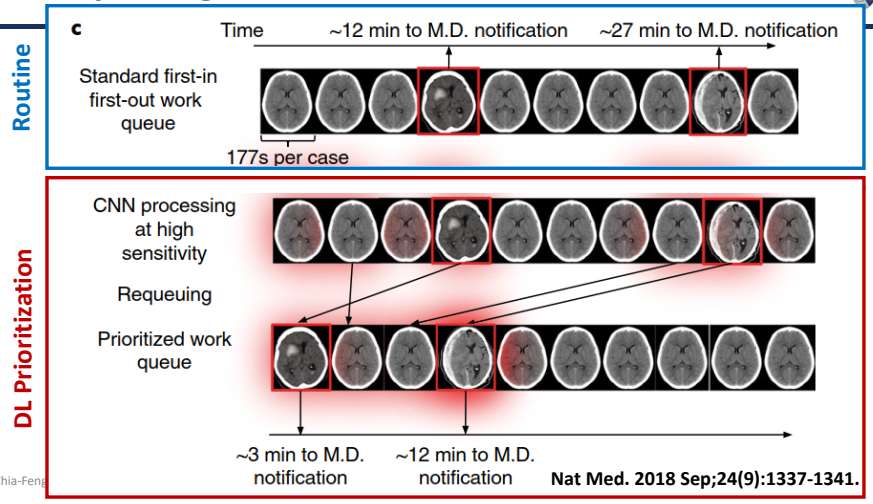
The changing workflow with AI

Qualitative → (auto/semi-auto) quantitative



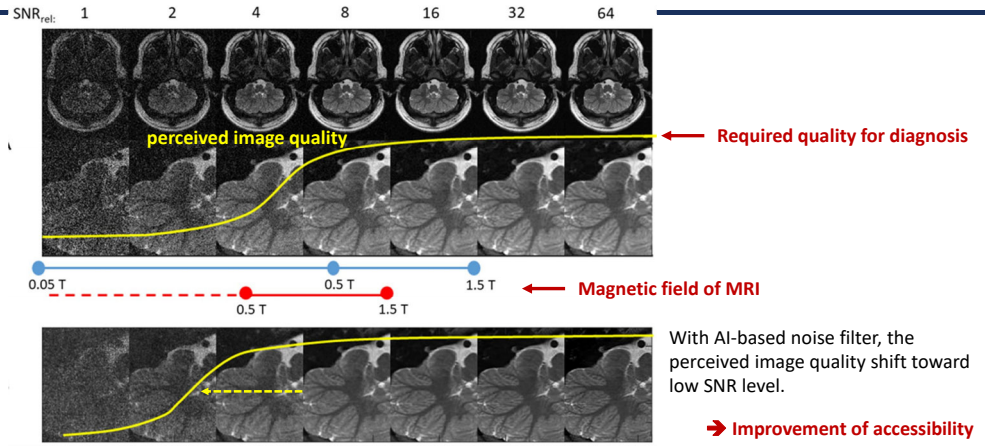
Journal of Medical Imaging and Radiation Sciences 50 (2019) 477-487

Emergency Triage – Prioritization of Reporting Workflow



Nat Med. 2018 Sep;24(9):1337-1341.

Denoise of low-field MRI



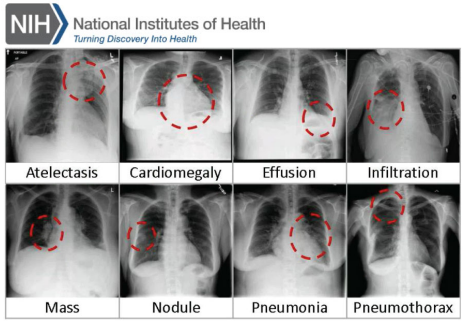
With AI-based noise filter, the perceived image quality shift toward low SNR level.

→ Improvement of accessibility

Magnetic Resonance Materials in Physics, Biology and Medicine. 2023 Jul;36(3):335-46.

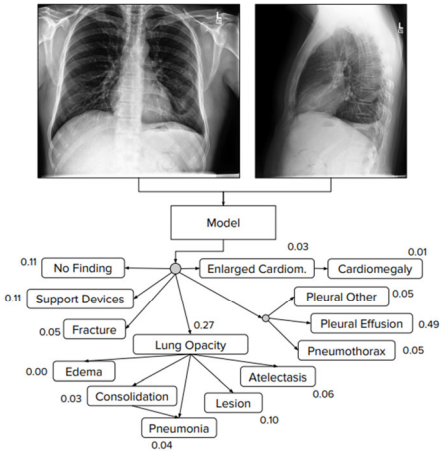
Disease Classification/Detection in Chest X-ray

- Provided by NIH Clinical Center, 2017
  - https://nihcc.app.box.com/v/ChestXray-NIHCC/folder/36938765345
- Overall 112,120 chest x-ray images from 30805 patients
- Covering 14 common chest diseases
  - Atelectasis; Cardiomegaly; Effusion; Infiltration; Mass; Nodule; Pneumonia; Pneumothorax; Consolidation; Edema; Emphysema; Fibrosis; Pleural Thickening; Hernia
- With bounding box locating lesions in 984 images

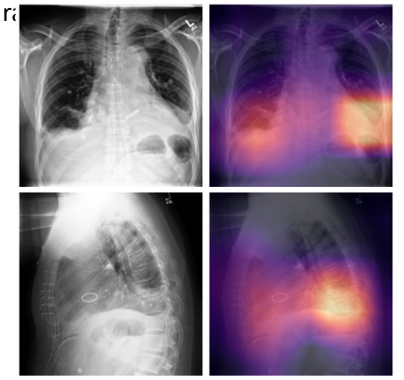


CheXNet: Radiologist-Level Pneumonia Detection on Chest X-Rays with Deep Learning
Wang et al. ChestX-ray8. IEEE CVPR 2017

CheXpert: A Large Chest Radiograph Dataset with Uncertainty Labels and Expert Comparison (2019)

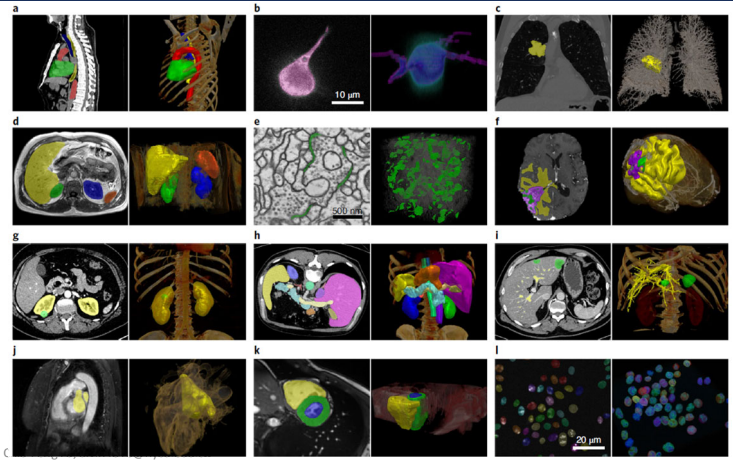


To predict the probability of different observations from multi-view chest r



bilateral pleural effusions

nature methods — Image segmentation



nnU-Net
a self-configuring method for deep learning-based biomedical image segmentation

Nature methods, *18*(2), 203-211, 2021.

AI-based Medical Imaging Systems With FDA Approval

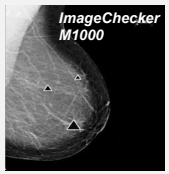
Software	Company	Imaging Data	Description
SubtlePET/ SubtleMR	Subtle subtlemedical.com	PET/ MRI	Enhancement of PET/MR images
LungAI LiverAI	Arterys www.arterys.com	Lung CT Liver CT, MRI	Segmentation of lesions and nodules
AmCAD-UT	AmCad BioMed www.amcad.com.tw	Thyroid ultrasound	Characterisation and assessment of thyroid tissue
IDx-DR	IDx www.eyediagnosis.co	Retinal	Feedback on image quality, and instructions for patient follow-up or referral
icobrain	Icometrix icometrix.com	Brain MRI, CT	Interpretation of CT and MRI brain images
OsteoDetect	Imagen www.lify.io	Wrist X-ray	Detection of distal radius fracture
AI1	Zebra Medical Vision www.zebra-med.com	CT, X-ray of various diseases	Detection and quantification of abnormalities
Aidoc Head/Chest/Spine/Abdomen	Aidoc www.aidoc.com	Radiology images	Detection of acute abnormalities across the body
ProFound AI	iCAD www.icadmed.com	2D mammograms	Detection of malignancies and calcifications
Transpara	ScreenPoint Medical screenpoint-medical.com	2D and 3D mammograms	Detection and likelihood of cancer
Accipio	MaxIQ AI http://www.maxq.ai/	Head CT	Triaging of intracranial haemorrhage
Paige AI	Paige https://paige.ai/	Digital slides	Diagnosis for digital pathology

IEEE Journal of Biomedical and Health Informatics, 24(7):1837-1857, 2020.

FDA Approved AI Systems

電腦輔助偵測 (Detection, CADe)

標記病灶位置，協助醫師偵測病變或不正常值

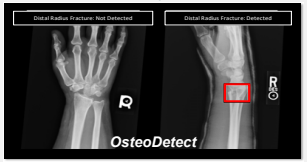


電腦輔助診斷 (Diagnosis, CADx)

提供量化診斷數據，如良/惡性病變之鑑別、病況發展情形

電腦輔助偵測及診斷(CADe/x)

透過機器學習演算法偵測/診斷疑似癌症或骨折。



分流與提醒 (Triage, CADt)

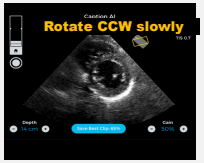
透過機器學習、人工智慧等演算法，來提供分流與通知的功能

ContaCT

影像擷取與優化 (radiological acquisition and/or optimization, CADa/o)

提供回饋及操作導引，以改善醫學影像/訊號擷取之品質。

透過深度學習演算法進行影像分析，以引導使用者取像



Caption Guidance

獨立診斷 (autonomous diagnostic system)

可在無醫事人員監督下，進行特定疾病之診斷。

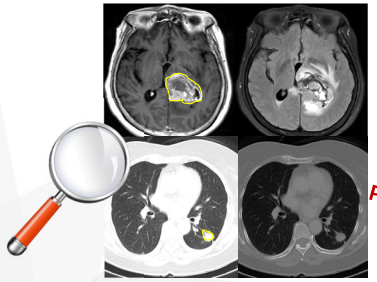
以人工智慧演算法確認患者是否患有視網膜病變

IDx-DR

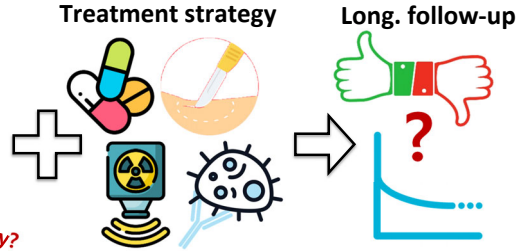
Development of Medical Image AI

Stage I: Lesion detection & diagnosis
(能人所能及，提升效率)

Stage II: Outcome prediction
(能人所不能，開創精準醫療)



Pathology? Malignancy?



Aim: Reduction of labor-intensive routines and misdiagnosis rate.

Aim: Identification of suitable treatment strategy for personalized medicine.

New business models of smart healthcare.

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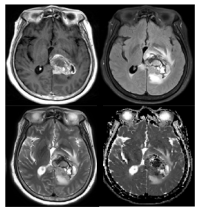
Applications of Radiomics/Radiogenomics

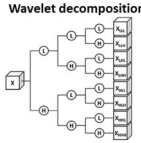
Macroscale
(whole tumor volume/peritumoral region)

Multi-parametric MRI



T1+C: Solid tumor (vascularity)
Central necrosis
DWI/ADC: Cellularity
FLAIR: Peritumoral edema
T2W: Cystic component

Radiomics with Machine Learning



Quantitative imaging features
(+ clinical features)

A.I.
Machine/deep learning

Microscale
(cells/genes/metabolisms)

Histology/Malignancy

Molecular/genomic Profiles

Future events
(treatment response/prognosis)

Outcome prediction
(local control/overall survival)

Side effects/Complications

Clinical applications

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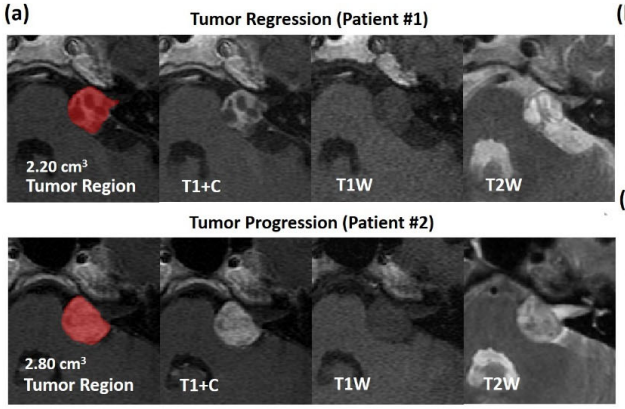
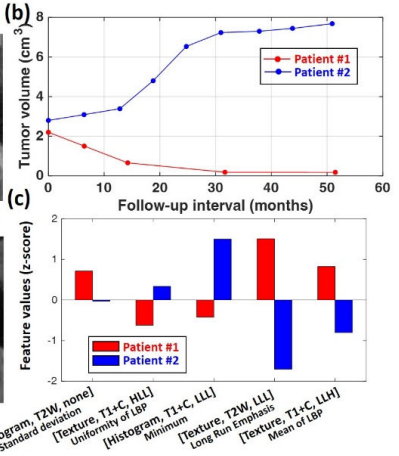
Prediction of Final Outcome





Yang et al. Radiotherapy and Oncology, 2021.

Critical Issues of AI in Medical Imaging

- Image formation and acquisition
- Interoperable and fair data repositories for reproducible, extensible and explainable research
- Processing, analysis, and understanding in radiology
  - *Feature analysis*
  - *Machine learning & deep learning*
  - *Interpretation and understanding*
- Visualization and navigation
- Integrative analytics
  - *Medical imaging in the era of precision medicine*
  - *Radiogenomics for integrative analytics*

IEEE Journal of Biomedical and Health Informatics, 24(7):1837-1857, 2020.

How medical AI devices are evaluated

Nature Medicine. 2021 Apr 5:1-3.

Most evaluations perform only retrospective studies.

- Almost all of the AI devices (126 of 130) underwent only retrospective studies at their submission, based on the FDA summaries. None of the 54 high-risk devices were evaluated by prospective studies.

The number of evaluation sites and samples are often not reported.

- Evaluating the performance of AI devices in multiple clinical sites is important for ensuring that the algorithms perform well across representative populations.

When do you expect AI use cases to become mainstream (at least 20% penetration into radiology)

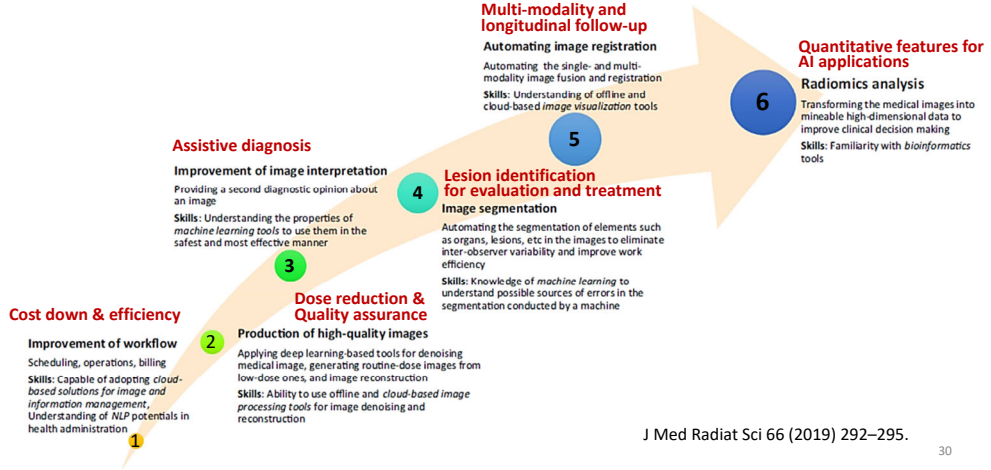
Number of respondents (n = 50 radiologists)

High — Low

Respondent answer	Triaging images to move most critical patients to first review	Optimizing workflow for overall productivity	Automating part of image analysis	Providing clinician-decision support	Enhancing imaging quality	Identifying new indications
It is now	6	7	7	10	15	4
In next 1–3 years	20	21	16	17	19	16
Within 5 years	10	15	10	11	11	16
Within 10 years	13	5	13	9	4	9
In >10 years	1	2	4	3	1	5

Journal of American College of Radiology, 2020;17:165-170.

AI Areas of Impact for Medical Imaging



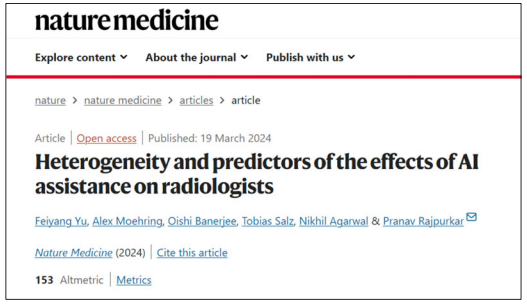
J Med Radiat Sci 66 (2019) 292–295.

Does AI Help or Hurt Human Radiologists' Performance? It Depends on the Doctor

HARVARD MEDICAL SCHOOL

New research shows radiologists and AI don't always work well together

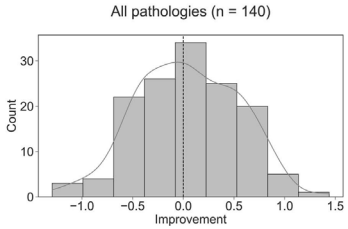
- Study shows AI improves performance for some radiologists but worsens it for others.
- Understanding who might benefit from AI and who would not is critical for designing tools that boost human performance.
- The findings underscore the importance of tailored AI-clinician integration over a one-size-fits-all approach.



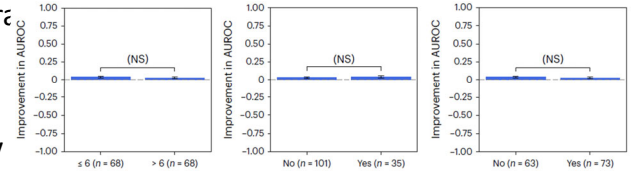
https://hms.harvard.edu/news/does-ai-help-or-hurt-human-radiologists-performance-depends-doctor

AI affects different radiologists differently

- AI influence human performance unpredictably.
  → complex nature of machine-human interaction
- AI developers should work with physicians to understand the precise factors that come into play in the human-AI intera



CheXpert AI tool, Stanford University
https://stanfordmlgroup.github.io/competitions/chexpert/



Years of experience | **Specialty in thoracic radiology** | **Experience with AI tools**

Outlook of AI in Medical Imaging

- Investments in AI-based medical imaging continue to grow exponentially.
  - The number of companies in the space has tripled, and investments have more than doubled to $1.17 billion.
- Despite these investments, AI solutions have not yet been adopted at scale in medical imaging.
- Physician adoption and regulatory approval are the two biggest barriers to broader AI deployment.
- AI is likely to gain ground quickly in the use cases (e.g., optimizing physician workflow, imaging quality, image triage, clinician decision support).

Open-Ended Questions…

- What are the roles of humans and machines in this AI era of Radiology? How do humans collaborate with machines?
- What is the potential benefit/applications of machine learning in your research?

Thanks for Your Attention :)

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