

出國報告（出國類別：其他）

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摘要

此次公差主要是參加 11 月 27 日至 12 月 1 日北美放射學會舉辦的 **Radiological Society of North America** 國際研討會。該會議為全球最大的放射科學頂級會議，展示當前最新學術研究與儀器技術新知，涵蓋廣泛的醫學影像相關主題，包含「造影系統」、「影像重建」、「電腦輔助診斷」等議題，特別是「人工智慧」放射成像技術最新科技與多項產品應用，可作為後續本所技術精進或結合的發想來源，相關資料及心得亦供計畫同仁參考。

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一、目的

配合近年來生技醫療產業導入人工智慧趨勢，結合本所放射領域知識，研發智慧化放射醫材與軟體平台。為蒐集人工智慧於放射影像與醫材相關應用與最新國際發展資訊，參加 2022 Radiological Society of North America 國際研討會，該會議為放射科學頂級國際會議，議程包含放射醫學、醫學影像與人工智慧等領域學術演講與技術，藉此掌握人工智慧的數位發展趨勢，此次蒐集相關資訊將為本計畫後續研發策略有所助益，並作為後續研發人工智慧輔助診斷軟體之參考。

二、過 程

(一) 行程：

日期	地點	內容
11 月 27 日~ 12 月 01 日	美國 芝加哥	線上參加 2022 Radiological Society of North America 國際研討會

(二) 2022 Radiological Society of North America 國際研討會介紹：

2022 Radiological Society of North America 國際研討會(RSNA 2022)由北美放射學會於美國芝加哥的 McCormick Place 舉辦，重點介紹最新的醫學影像研究和教育，特別是結合近幾年的人工智慧，並強調醫療領域中同理心、多樣性和公平性的重要性。RSNA 2022 是全球最大的放射論壇盛會，包含了 900 多篇論文發表、1,300 多篇海報、300 多門教育課程和 1,450 多件展示品，其中共有 644 家參展廠商現場展示了電腦斷層掃描(Computer Tomography, CT)、磁核造影檢查儀(Magnetic Resonance Imaging, MRI)、人工智慧(Artificial Intelligence, AI)等領域的最新醫學成像技術，與會人數高達 38,000 人(包含醫師、放射師、學生、廠商等)。因 COVID-19 疫情關係促使數位經濟與線上異地會議的盛行，RSNA 2022 有開放線上參加並提供方便的 APP 作部份內容回播，相關議程詳見附錄。

本次大會主要內容聚焦在人工智慧、大數據、雲端服務等數位技術對於整個放射影像的改變與影響，半數以上主題均跟這些內容有高度相關，並共有 327 場教育課程，期望所有的醫師、放射師等與會人士能對這項技術變革有初步認識，它是協助放射科醫生進行疾病檢測和改進放射學工作流程的重要工具。除了教育課程、關鍵演講、學術發表與電子海報以外，本次大會有新增兩個特別的主題區：「AI Showcase」和「AI Theater」，「AI Showcase」讓與會者能夠直接與廠商聯繫，藉此瞭解最新的 AI 產品，特別是在如何讓 AI 實踐與落地的商業面向；「AI Theater」舉辦了多場 AI 相關演講與成果，例如 RSNA 頸椎骨折 AI 挑戰賽的解題方案，或是使用臨床場景來展示 AI 工具實際應用，像是影像檢查報告或改善放射學工作流程。

三、心得

(一) 人工智慧新穎放射成像技術

人工智慧中的深度學習(Deep Learning)在電腦視覺、自然語言、推薦系統等領域有許多突破，自 2016 年之後更是迎來高速發展，改變了整個放射成像技術的格局，包含影像重建、影像校正、低劑量、高解析度等議題均全使用深度學習，技術主要為卷積神經網路(Convolutional Neural Network, CNN)(最常被使用的是 U-Net)、自編碼(Auto-Encoder)(包含它的家族 Variational Auto-Encoder 與 Masked Auto-Encoder)、變形器(Transformer)(特別是 ViT)、生成對抗網路(Generative Adversarial Network, GAN)等方式建構深度學習神經網路模型，再搭配自我監督式學習(Self-Supervised Learning)和遷移學習(Transfer Learning)等技術進行訓練，改善訓練資料標記不足與不易泛化(Generalization)的痛點，例如演講「Transforming Radiograph Imaging with Transformers」中，來自 Johns Hopkins University 的 Junfei Xiao 講者就針對以上技術作了一個快速回顧。最新的前沿技術部份包含擴散模型(Diffusion Model)、知識圖譜(Knowledge Graph)等，探討如何將醫師的知識放入並與傳統演算法結合。

1. 影像重建(Image Reconstruction)：

「Deep Learning in Imaging Formation」場次由淺入深提到整個深度學習導入影像重建的歷史與技術演進，有別於傳統濾波反投影(Filtered Back Projection, FBP)或迭代重建，利用深度學習可更加提昇影像品質。如圖一所示，GE、Philips 等各醫療大廠已推出深度學習影像重建(Deep Learning Image Reconstruction, DLIR)的醫療儀器產品，由於大廠均有大量的數據可供模型訓練，大多採用自編碼(Auto-Encoder)的模型架構進行設計，利用編碼器(Encoder)將多張 2D 投影數據投影到高維潛在變量空間(Latent Space)，可視作電腦對於影像的理解，再利用解碼器(Decoder)重建出 3D 影像，例如 GE 的產品 TrueFidelity 是採用 U-Net 模型，以過往的數千筆數據進行訓練，作到劑量再次減半(造影張數減半)並已通過美國 FDA。

在少量角度影像重建的部份，如圖二所示，新穎技術甚至開始能利用兩張 2D 投影資訊來重建 3D 影像，像以色列的 Zebra 公司已有推出這類型產品，該技術使用

生成對抗網路(Generative Adversarial Network, GAN), 整合成一個端到端(End-to-End)的方式進行訓練, 並搭配不同的條件以多個損失函數整合其他模型, 例如去雜訊模型, 如圖三所示, 改善少量角度造影的低劑量雜訊。現在最前沿技術是使用神經放射場(Neural Radiance Fields), 將深度學習結合射束覓跡(Ray Tracing)作立體渲染(Volume Rendering), 生成不同角度的 2D 投影資訊。

綜觀整個影像重建的技術發展, 有限角度影像重建的技術趨於成熟, 從早期的專家規則演算法到以統計為主的迭代演算法, 再到以數據為中心的深度學習演算法, 極少量角度成像目前偏向實驗室階段, 但已具有潛力能作到兩張 2D 重建 3D 影像或是以單張 X 光區分材質。未來技術發展會從縱向改為橫向水平整合, 如圖四所示, 將超解析度深度學習模型應用在 2D 投影後, 再進行影像重建來提升整體影像品質, 可見下一步是將其它模型與重建模型作更好的整合。

產品部份雖然可穩定以深度學習作到高品質成像, 但如圖五的腫瘤影像所示, 深度學習有可能造成影像的退化; 跨不同場域的泛化(Generalizability)問題更為嚴重, 如圖六所示, 一旦實際臨床場域的影像和訓練資料差異甚大時, 深度學習模型表現非常差, 現階段的領域自適應(Domain Adaptation)演算法仍有其侷限, 可見未來在技術發展會更側重實際臨床數據的適應能力, 並著重在改善不同機台的泛化能力與模型穩定性。

2. 影像處理(Image Processing) :

低劑量、假影抑低、衰減校正等議題使用深度學習來改善影像品質, 使高階放射成像儀器的品質全面提升。以低劑量的去雜訊模型為例, 如圖七所示, 該團隊利用 Noise2Noise 模型對影像進行去雜訊的訓練, 由於訓練資料的標記不易取得, 先自行製造大量的統計模擬雜訊用於訓練, 再以 PCD CT(Photon-Counting Detector CT) 得到少量標記影像進行微調(Fine-Tuning), 該技術也能與 PCD CT 整合進行材質解析。為改善造影數據難以取得並加強每位病患的個體化差異, 如圖八、圖九和圖十所示, 透過同一張影像不同的 Patch(切分出的子影像), 若為雜訊影像則無法分辨出 Patch 所在位置, 巧妙的建構出自我監督式學習來作到單樣本學習(One-Shot Learning)。

深度學習在儀器的校正扮演非常重要的角色，它可使用更精確的其他造影方式，例如 PCD CT 或是 Dual-Energy 等，產生訓練數據來從旁輔助，由它們扮演老師的角色，搭配知識蒸餾(Knowledge Distillation)等技術修正模型，如圖十一和圖十二所示，以上技術被用於改善較小可視範圍造成的截斷誤差(Truncation Error)。另一種作法是生成對抗網路，直接生成不存在的 CT 進行衰減、散射等校正，如圖十三和圖十四所示，該團隊利用生成對抗網路從正子斷層造影(Positron Emission Tomography, PET)影像產生對應的 CT 影像，再利用 CT 影像進行 PET 影像衰減校正，有別於傳統的假體作法，深度學習校正方式較能反映出個體差異，對病患高矮胖瘦作修正。生成對抗網路也能用來解數據一致化問題，如圖十五所示，該病患使用 Siemens 儀器進行造影的影像，透過生成對抗網路想像出該病患若使用 GE 儀器拍攝的樣貌。

另一個非常有趣的應用是作位移補償(Motion Compensation)，CT 在拍肺部時由於病患會呼吸而造成成像模糊，可使用不同範圍的部份 2D 投影各自作小角度重建，再搭配深度學習計算出不同時間點的偏移量(Offset)，最終於重建時進行校正，效果如圖十六所示，有別於傳統方式需另外由儀器測量心率和呼吸，再同步至 CT 儀器，該作法可直接對影像個別化進行校正，減少病患心臟跳動、肺部呼吸等物理現象對影像的模糊化現象。

比起常見的深度學習應用，例如事後の影像分類、物件偵測、影像分割等，將深度學習結合硬體後用於儀器校正，更能幫助放射或核醫影像，但這部份需事先與儀器商合作進行才能取得儀器訊號。預期未來的發展方向應為軟硬整合，特別是邊緣裝置(Edge Device)與算力，讓每台儀器有個體化差異並針對自我個體適時校正，軟體技術較為前沿的方向是內嵌物理知識神經網路(Physics Informed Neural Network, PINN)，將傳統物理現象與神經網路作完美的融合，再導引前述校正的技術走向更準確的方向。

3. 影像品質(Image Quality)：

由於深度學習模型技術是一個黑盒子，如何客觀評斷結果變為非常重要，萬一模型有誤判是否能提前警示醫師或放射師、將結果好壞回饋給模型進行學習、讓模

型對於影像的觀感與人類一致等「影像品質」議題是本次大會的主軸，比較特別的是觀測影像品質或實現上述目標的作法，大多使用深度學習的技術來節省人力。

觀察 AI 發揮是否穩定在統計上的說法是模型本身的變異性(Variance)，AI 可以是傳統機器學習或是深度學習，一種作法是改變訓練集的配比，訓練多種 AI 模型，使用整體學習(Ensemble Learning)進行投票，當不同 AI 模型之間意見差異甚大也給予評分，如圖十七所示，過高的評分表示 AI 模型對於該案例是不確定的(Uncertainty)，藉此告訴醫師或放射師，後續當醫師或放射師依據自身經驗作出判斷後，再使用整體學習的堆疊法(Stacking)或連續學習(Continuous Learning)修正 AI 模型們的決議與投票方式。

觀測影像品質可建立一個深度學習模型給予評分，或是整合成端到端(End-to-End)的架構作品質控制(Quality Control)，以「a deep quality assurance network for AI in CT applications」演講為例，如圖十八所示，先使用 Dual-Energy CT 產生不同材質的 Sinogram 影像，訓練一個品質控制的深度學習模型，可融合不同材質的 Sinogram 影像為 CT 影像。接下來訓練另一個深度學習模型，直接從 CT 影像預測不同材質的 CT 影像，如圖十九所示，預測出來後作一個正向投影(Forward Projection)轉換產生 Sinogram 影像，再丟給品質控制模型，最終得到預測假想的 CT 影像，繞了一圈可和原本 CT 影像去作比對，如圖二十所示，兩者影像相減差異較大的位置，就是整個深度學習模型在成像過程中作得比較不好的部份。跟 Grad-CAM 演算法猜想模型關注位置不同，它是藉助了其他儀器或造影方式來扮演老師模型(Teacher Model)。

一般的深度學習模型只適應它見過的訓練數據，對於未知測試數據的往往適應能力不佳，若搭配連續學習改善此現象，容易產生資料下毒(Data Poisoning)或模型飄移(Model Drift)等現象，為增加模型本身的穩健性(Robustness)，可利用生成對抗網路來改善此現象，如圖二十一所示，講題「Who is watching the AI: computational solution」對變分自編碼(Variational Auto-Encoder, VAE)的潛在變量空間接上判別網路(Discriminant Network)，避免錯誤生成，再透過數據位移直接對潛在變量空間作資料擴增(Data Augmentation)上的分群，如圖二十二所示，強化該空間的集群(Cluster)效

果。

影像品質評分與穩定性均使用深度學習，但因沒有正確的參考物(No Reference)，需使用以生成對抗網路為主的技術作非監督式學習(Unsupervised Learning)，技術進入門檻高。由於近幾年深度學習對於潛在變量空間的掌握能力越來越好，像近期的流量生成模型(Flow-Based Generative Model)、擴散模型(Diffusion Model)等，可預期未來會直接在潛在變量空間作評分與排名，並將醫師的判斷直接接到此空間。

4. 自然語言處理(Natural Language Processing)：

本次大會主題最令人驚豔的是有更多處理文字的深度學習模型與應用，例如「NLP and Report De-Identification in Abdominal Radiology Reporting」介紹使用文字技術直接讀放射報告，一般訓練影像模型需要大量的標記資料，而醫師或放射師往往沒空進行圈選，由於 2017 年基於 Transformer 的雙向編碼器(Bidirectional Encoder Representations from Transformers, BERT)，使整個文字領域走向預訓練模型(Pre-trained Model)，現今的深度學習能輕易作到從報告中摘錄重點並整理內容，從過往的病歷或報告分析出影像的標記。

2021 年年底連接文本與影像(Contrastive Language-Image Pre-Training, CLIP)技術成熟，在潛在變量空間利用集群(Cluster)把文字與影像對齊在同一個位置，搭配後來的擴散模型(Diffusion Model)技術，在高維空間將文字與影像融合在一起，建立兩者之間的橋樑，也在人工智慧自動生成內容(AI Generated Content, AIGC)掀起一波風暴。例如「Rethinking the Role of Data in Radiology AI」介紹使用自我監督式學習將擴散模型應用在胸腔 X 光影像，如圖二十三和圖二十四所示，X 光影像直接與文字對應，想像未來放射師可以直接用說的，例如「左下角的腫瘤、下面一點，再大一點，放大一下...」等口語化內容，影像配合放射師的語音作對應的變化，AI 更瞭解肺是什麼、肝是什麼，而不是歐幾里德空間的一個二維矩陣。

自然語言技術在處理影像已不可或缺，現在最普及的影像技術 Transformer 與 Attention 都是將自然語言技術應用在影像，現今的擴散模型更直接讓我們看到兩者合而為一，此技術能代換其他的生成對抗網路，生成更準確的人體器官，也是未來

幾年內不可或缺的主流趨勢。預期後續會直接使用自然語言技術轉換醫師的專業知識，使用圖神經網路(Graph Neural Network, GNN)建構知識圖譜，再與擴散模型的潛在變量空間整合，另外由於自然語言技術的廣泛應用與技術壁壘的突破，影像操縱(Image Manipulation)、影像理解(Image Understanding)、基於內容的影像檢索(Content-based Image Retrieval)等領域會是未來的發展方向。

(二) 平台整合與品質確保

人工智慧中的深度學習技術帶來非常大的變革，以數據為主的演算法對法規、專利、硬體、市場、平台、隱私、倫理等所有面向都是機會，技術落地需要橫向整合這一切，多場演講針對前述各議題進行討探與分享，例如大會第二天的關鍵演講「Translational AI Science: Bringing Advances in Deep Learning into Clinical Practice」特別探討如何導入臨床場域，將 AI 與醫院現有醫學影像存檔與通信系統(Picture Archiving and Communication System, PACS)結合等。

「CT Protocol Standardization: the Foundation for Successful AI」提到了挑戰與制定 AI 標準，如圖二十五與二十六所示，包含了「正確的數據」、「整合 AI 至臨床流程」、「長期維護更新」、「獲得醫師信任」等切入落地最重要的關鍵；「Failures, Biases, and more: When Good AI Goes Bad」提到 AI 模型本身距離落地有非常多的挑戰，如圖二十七所示。

整理所有演講重點如下：「AI 的強項可能是在預防，現階段於診斷和治療擔任配角」、「資料治理(整合)是發展個人化/精準醫療最重要的關鍵」、「圍繞在 AI 技術的道德、法律等議題遠比 AI 技術本身重要」、「醫院各自為政，並建立 AI 相關平台，但標準化大多僅作用於自身(縱向)，難以應用至其他醫院體系，需要建立標準」、「診斷或治療難以立刻切入的當下，老人照護(監測)和預防醫學會是 AI 先能開花的領域」、「改善醫學和管理流程是另一個重要的應用，特別是與資料的基礎建設扣合，並節省醫生的寶貴時間」、「統一、互通、不同參與者、通用源自於整合，是最大的挑戰」、「隱私和透明度是天平蹺蹺板，本身命題是互斥的，資訊安全(密碼學)也許將扮演重要角色(像是對數據加密之後作訓練)」、「有病才會看醫生，間接使醫院數據往往在不自覺的情況

下有偏見，健康數據的品質確保是一大難題(學術常用臨床試驗來應對)」、「如何確保人工智慧系統在運作過程正確性是最大挑戰，需聚焦在建立該系統的數據、資料庫等，由源頭的數據作確保是可行的方式」、「部署後隨著使用而更新 AI 模型、需要確保使用過程中的定期檢查、驗證與召回」、「過去醫療判斷是專業與道德，從醫生主觀的認定轉為人機互動是非常困難的，甚至於排斥，因此在醫療場域推動人機協作的文化會是重點」。

1. 醫學影像鏈(Medical Imaging Chain)：

為了融合 AI 與臨床場域，需將它與現有工作流進行整合，如圖二十八、圖二十九所示，整合後的數據流、AI 更新、面向使用者需動態更新。以 CT 造影為例，雖然 CT 放射造影的流程在儲存影像時已存放前端儀器資訊，但 AI 模型作泛化或儀器適應的技術仍困難重重，如圖三十所示，挑戰在於跨不同廠牌、儀器校正頻率、放射師拍攝病患時手動調整的參數等差異，而且無法即時反饋，或是卡在無法與現有系統整合，例如將最佳化參數從醫院端「自動」回傳至前端儀器，往往需與儀器原廠合作才能實現「自動化」流程，且只適用於本院而難以用於其他醫院。

在大會第一天的關鍵演講「Business of Imaging AI」稱整個概念為醫學影像鏈(Medical Imaging Chain)，優點是資料獲取階段的上游 AI 就能介入與瞭解，一路串接到 AI 模型的品質與安全性，多場演講依據此概念探討 AI 模型表現，例如「AI real-time feedback during clinical workflow」演講探討如何實現雙向互動與追蹤，並在臨床上得到 AI 的即時回饋。

演講「Applications Throughout the Radiological Imaging Chain」對醫學影像鏈作一個很好的實現與詮釋，圖三十一介紹了醫學影像鏈基本架構，圖三十二加入戰情室(Dashboard)供臨床醫師或放射師即時監控整個數據流與影像品質，該過程還能加入警示(Alarm)機制在 AI 表現可能失常或數據不正確時予以提醒，也能從平台反饋醫師或放射師的建議與想法，圖三十三從技術面介紹如何執行，以及現有健康資訊交換第七層協定(HL7)、快捷式醫療服務互操作資源(FHIR)、元數據(MetaData)等標準、技術與框架，圖三十四總結了落地的關鍵，整個成像平台涉及的面向極廣，且需大量資訊人力支撐整個基礎建設。

另一場演講「AI for Radiology Workflow: Private Practice」介紹如何使用 AI 來建構整個醫學影像鏈與數據資訊，例如 AI 觀察畫面螢幕，如圖三十五所示，以自然語言和影像處理方式從畫面上資訊和醫師操作產生對應的元數據，或是利用 AI 針對不同來源的數據作特徵提取(Feature Extraction)，如圖三十六所示，產生其他間接過程資料，例如元數據、文本分詞(NLP Tokenization)等，用以整理、比對、追蹤、交換與除錯。

軟體平台現在是贏者全拿的世代，而 AI 需要以它為基底才能落地，特別是從中以數據流方式建立數據庫，且後續的維運遠比前期研發來得重要，更需要支撐整個營運體系，一般中小型企業需要跨域橫向合作，以聯盟體系來打群架，再從平台以使用者友善(User Friendly)的角度多向發展。未來結合各類深度學習技術能進一步作到自然的使用軟體，像是以語音直接操控、自動整理分類摘要報告、結合 VR/AR 等技術作遠距醫療與數位雙生、以攝影機記錄醫師的眼睛盯哪邊，自然回收比較重要的資訊作訓練與反饋等。

2. 品質確保(Quality Assurance)：

軟體平台必須得作品質確保，並符合法律、倫理等規範，如圖三十七所示，由於現在的 AI 是利用數據而產生，數據也會流動，需要從數據本身即時監測與驗證，它並非是一個靜態工具，而是需要伴隨 AI 作動態適應，包含觀察每一筆新進的數據、監控 AI 的表現、確認軟體平台運作正常。因此研發戰情室作戰情分析非常重要，將前述監控結果作視覺化呈現，並在發生異常時能「自動」通知或警告，這些技術也能導入深度學習來作更精確的異常偵測或預判，如圖三十八所示，它能即時反映 AI 模型表現。

考量病患隱私與資料不離開醫院等議題，又希望能與聯邦學習(Federated Learning)進行整合，大多醫院資訊系統採用端雲共生系統，如圖三十九所示，將 AI 模型放置於雲端，此情況下包含資料傳輸在內均需作品質確保，如圖四十所示，地端自身醫院的數據可由戰情室監控，將它與病患或影像特徵整合，能進一步與軟體平台互動，分析個體臨床數據。聯邦學習在大會中也是熱門議題，如圖四十一和圖四十二所示，均使用端雲共生將個資保留在醫院。聯邦學習框架非常龐大，它建構

在 AI 軟體平台之上，在醫院端接收異質性資料如 PACS、FHIR 等，並作數據品質確保，包含元數據、數據標記、數據清洗、數據安全性、去個資，之後在醫院端作 AI 模型的判讀，搭配加密技術回饋梯度向量至雲端，雲端再依據多個梯度向量作整體學習(Ensemble Learning)的聚合(Aggregation)產生全域模型(Global Model)，隨後下放至醫院地端作驗證調整與戰情分析，部份模型會停留在地端作動態適應。兩者傳輸過程需考量資料或模型中毒(Poisoning Attack)，也需防範對資料、模型、推論的惡意攻擊，並解決多醫院不同時間點梯度同步問題等，因而衍生出同態加密(Homomorphically Encrypted)聯邦學習等多項技術，最重要的是以上技術必須跟傳統資訊領域完美結合，要考量防火牆、CA(Certificate Authority)憑證、跳板、虛擬機、容器化等實際落地技術，建構出完善的數據流(Data Flow)。

AI 軟體平台品質確保及其通用性建構在數據之上，包含資料探索分析(Exploratory Data Analysis, EDA)和資料存取轉換載入(Extract Transform Load, ETL)，在「AI Governance in Medical Imaging: How to Herd the Cats and Avoid Chaos」等多場講座中提到人工智慧治理(AI Governance)，各國已開始依據數據與 AI 定義標準，作為流通與交換，特別是 AI 的泛化與通用性也遠比準確度來得重要。因大多數組織缺乏可擴展與持續的方式維運 AI，如何「管理」遠比發展 AI 來得重要，人工智慧治理與標準訂立將是 AI 世代下一個戰場。

(三) 人工智慧解題方案與產品展示：

1. 人工智慧挑戰賽：

RSNA 每一年都有舉辦放射影像人工智慧競賽，並將其放於 Kaggle 資料科學競賽平台，如圖四十三所示，2022 年的題目為 CT 影像頸椎骨折偵測，共有 883 隊報名參賽，訓練資料來自於 9 個國家共計 343.51 GB 的大型數據集，並請多位放射科醫師進行標記，框出在影像中頸椎骨折的位置，獎金為 3 萬美元，最終前幾名的團隊在現場各自發表解題方案並互相交流，相關技術能直接轉為期刊進行發表。

本次大會第一名 Qishen Ha 採用 2-stage 的兩階段作法進行處理，第一階段作 3D 的語義分割(Semantic Segmentation)，找出頸椎範圍，第二階段使用 2.5D 的影像搭配

長短期記憶網路(Long Short-Term Memory, LSTM)作分類模型。大會第二名 Ryan Rongu 也是採用兩階段作法，第一階段使用 2.5D 影像搭配 U-Net 產生遮罩影像，用以建構分割模型，第二階段融合 CNN、雙向門控循環(Bidirectional Gated Recurrent Unit, BiGRU)和注意力(Attention)機制直接進行分類。大會第三名 Darragh Hanley 採用全域平均池化(Global Average Pooling, GAP)建構 CNN 網路，並使用遷移學習(Transfer Learning)的凍結(Frozen)技巧，搭配語言模型的雙向 LSTM 與注意力機制串接不同切面影像。

透過比賽方式可看到各種解題方案花招百出，在相同的數據集下互相切磋比較，參賽者來自各大學術單位或是大廠研發團隊，決賽後相關程式均放在 Kaggle 競賽上或是進行開源(Open Source)，放置於 GitHub、Hugging Face 等平台。2023 年的競賽題目為 X 光乳腺癌檢測，如圖四十四所示，由於 AI 技術以指數倍的速度成長茁壯，平均每一天都有幾百篇相關期刊，該數字更是每三年成長四倍，尖端技術每一年都以「極速」更新，若是要培育尖端 AI 研究團隊，需全力以赴並定期參加相關比賽，習慣開源文化、物件導向與容器化概念。

2. 人工智慧產品展示：

「AI Showcase」和「AI Theater」有很多有趣的產品應用，AI 很好不代表它是必須品，從產品面向需考慮它是否能賺錢，一個醫療平台推出時誰來買單？是醫師、使用者、醫院還是保險公司，另外數據的數位商業模式是什麼，都是大家最關切的議題。以演講「5 Steps to Your AI Strategy: Enlitic」為例，David Wilson 介紹 AI 部署成產品的挑戰，如圖四十五和圖四十六所示，更是針從產品面向來看待 AI，該考慮的因素如圖四十七和圖四十八所示。最重要的在於是否能理解數據價值和數位生態系，改變傳統觀念，並理解它能帶來的長遠效益。

來自韓國的 Hye Weon Kim 展示了失智症腦科學平台 Neurophet 產品，該平台研發團隊有 30 位 AI 專家、60 多篇期刊發表與 100 多篇專利，目標是利用大數據來偵測是否有早期失智症，影像來源以核磁共振(Magnetic Resonance Imaging, MRI)為主，該軟體各功能於美國 FDA 申請狀況如圖四十九所示，它由政府大力支持，使用

8 家醫院共 3 萬筆以上的數據集來建立資料庫，如圖五十所示。技術部份採用 U-Net 的變形 SAU-Net 進行腦區影像分割，由放射師手動標記圈選進行訓練，如圖五十一所示，SAU-Net 利用注意力機制串接多張 2D 切面影像，並作緊密相連設計達到語義分割的效果，適合用作 3D 影像且非歐幾里德座標系的主幹模型(Backbone Model)，它的效果如圖五十二所示，能有效避免傳統作法在腦區分割的不連續面。腦區分割完後能直接對每個腦區進行圈選，可再結合 PET 影像(MRI 影像須跟 PET 影像作對位)，產生各數值進行量化預測，如圖五十三所示。有大量數據支撐整個平台體系，它可以開發多項功能，將數據轉換為其他價值，如圖五十四所示，例如腦出血偵測等，以臨床輔助決策系統角度切入市場，回收使用者回饋後形成數據循環(Data Cycling)，使平台成長茁壯。

四、建議事項

(一) AI 技術部份日新月異，伴隨第四波工業革命已成顯學，技術走向兩個極端，尖端 AI 技術發展極其迅速，另一類熱門的領域是 No-Code AI，不需要會寫程式，而是所有人都必須知道 AI 及其相關影響，大會中多場演講均提到所有醫師和放射師都需要瞭解如何應用 AI 工具，建議核研所研發團隊儘量導入數位文化，瞭解大數據、端雲共生、物聯網、區塊鏈、邊緣裝置等技術發展和它們伴隨的共生效應。

(二) 軟體平台研發最大的核心問題是數據，必須具有代表性、一致和準確，還需要技術可用性(數據格式、機器可讀性、安防性和存取選項)，作完後面臨三大挑戰如下：「AI 部署後持續學習的使用與驗證」、「人機協作文化與醫療場域的共識」、「法律配套的措施」，建議儘量掌握數據本質並與醫療場域專家一同進行軟體平台研發，實現數據流動。

(三) 軟體從電腦到網路，形成雲端後發展出大數據，再到 AI 普及，建構端雲共生的聯邦學習架構，數據以區塊鏈方式作分散式儲存，並以物聯網概念存放於地端，軟體平台需要考慮上述的內容橫向水平整合，以目前趨勢是遇到「標準化制定」、「泛化」與「資訊安全」議題，接下來隨著數據量增多與邊緣裝置的大幅成長，預期世界趨勢的關鍵是通訊與材料，算力部份是量子運算，再下一步會是數位雙生與數據交換。建議現在需特別關注「資訊安全」議題，橫向尋求聯盟共同發展軟體平台，並在通訊、材料、量子領域提前佈局。

五、附圖

MAYO CLINIC

Clinically Available DLIR

- ▶ CT vendors
 - GE: TrueFidelity (2019)
 - Canon: AiCE (2019)
 - Philips: Precise Image (2022)
 - ...
- ▶ Vendor-agnostic implementations (image-based denoising)
 - AlgoMedica: PixelShine
 - ClariPI: ClariCT.AI
 - ...

圖一、各大廠將深度學習應用在影像重建[1]

ScoutCT-Net: Neural Network

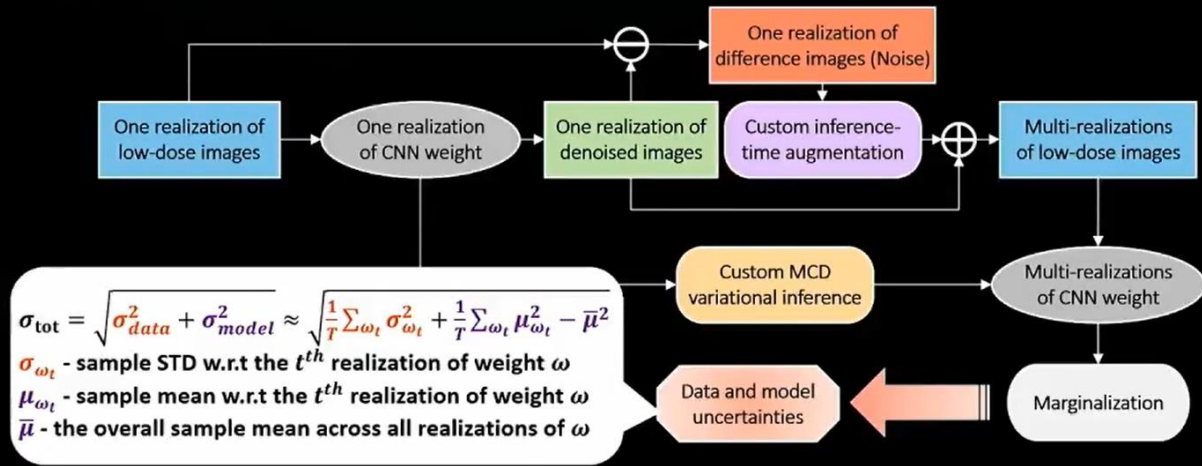
1. Montoya, Li, & Chen, Volumetric CT scouts from conventional two-view projection scout images using deep learning. AAPM Annual Meeting (2018);
2. Montoya, Zhang, Garrett, Li, & Chen, Three-dimensional CT scout from conventional two-view radiograph localizers using deep learning. RSNA(2018);
3. Montoya, Zhang, Li & Chen, Volumetric scout CT images reconstructed from conventional two-view radiograph localizers using deep learning. SPIE Medical Imaging, Conference (2019) Vol. 10948, 2019:1094825;
4. Montoya, Zhang, Li, Li, & Chen, Reconstruction of three-dimensional tomographic patient models for radiation dose modulation in CT from two scout views using deep learning. Med. Phys., Vol. 49:901-906(2022)

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圖二、少量角度影像重建技術模型介紹[2]

Uncertainty quantification pipeline

- **Marginalization** must be conducted to systematically quantify each uncertainty



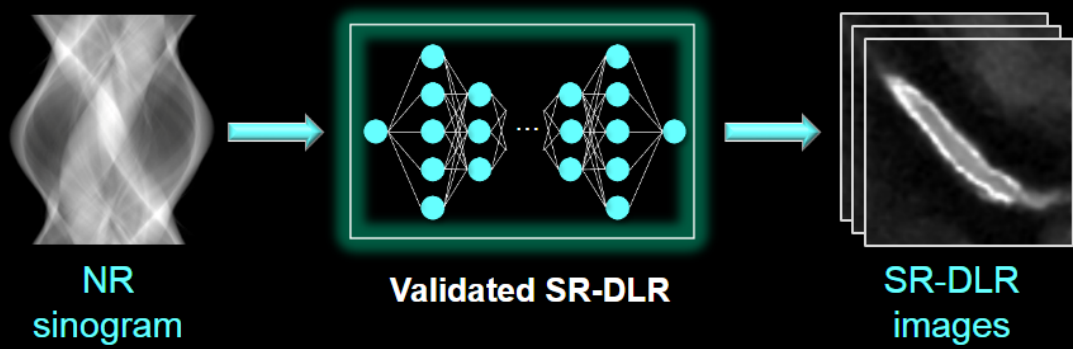
圖三、少量角度影像重建技術流程圖[3]

SR-DLR: Clinical applications

In the clinical environment, SR-DLR can produce the CT images with improved spatial resolution and reduced image noise on widely available NR CT scanner.

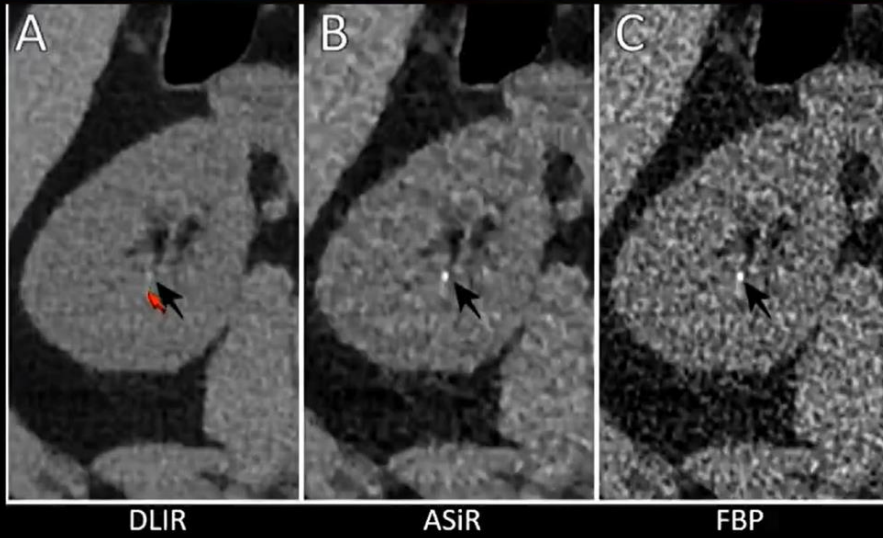
These benefits come with **no additional radiation dose** to the patients.

SR-DLR is implemented in 320-row area detector scanners that allows one volume cardiac imaging at single heart beat.



圖四、超解析度技術應用於 Sinogram [4]

Degradation of subtle lesion or structures



Delabie et al, Acta Radiologica 2021

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圖五、深度學習的影像退化現象 [1]

Generalizability

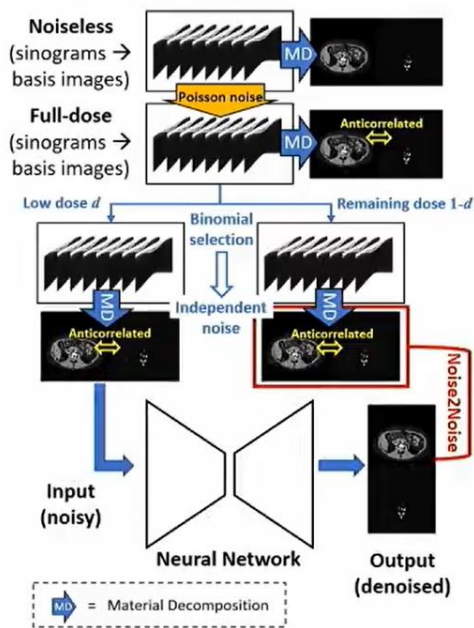
- When the network is applied to images that are not representatives in the training cases, it may lead to suboptimal performance

Huber et al. JCAT 2021

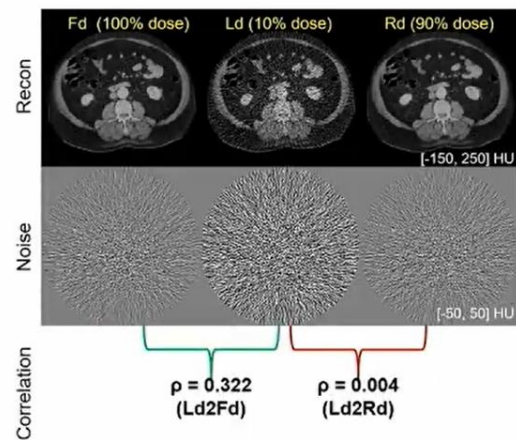


圖六、深度學習的泛化問題 [1]

Noise Independent Pair in PCCT



Noise independence preserved in image domain

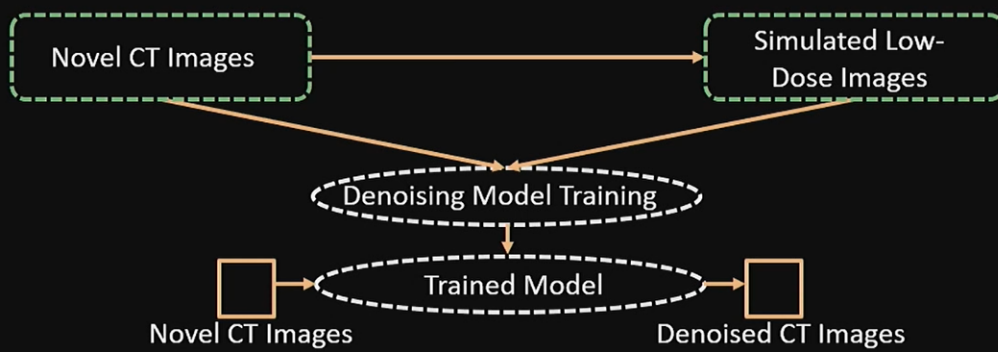


圖七、去雜訊深度學習應用在 CT 影像 [5]

Self-supervised Training

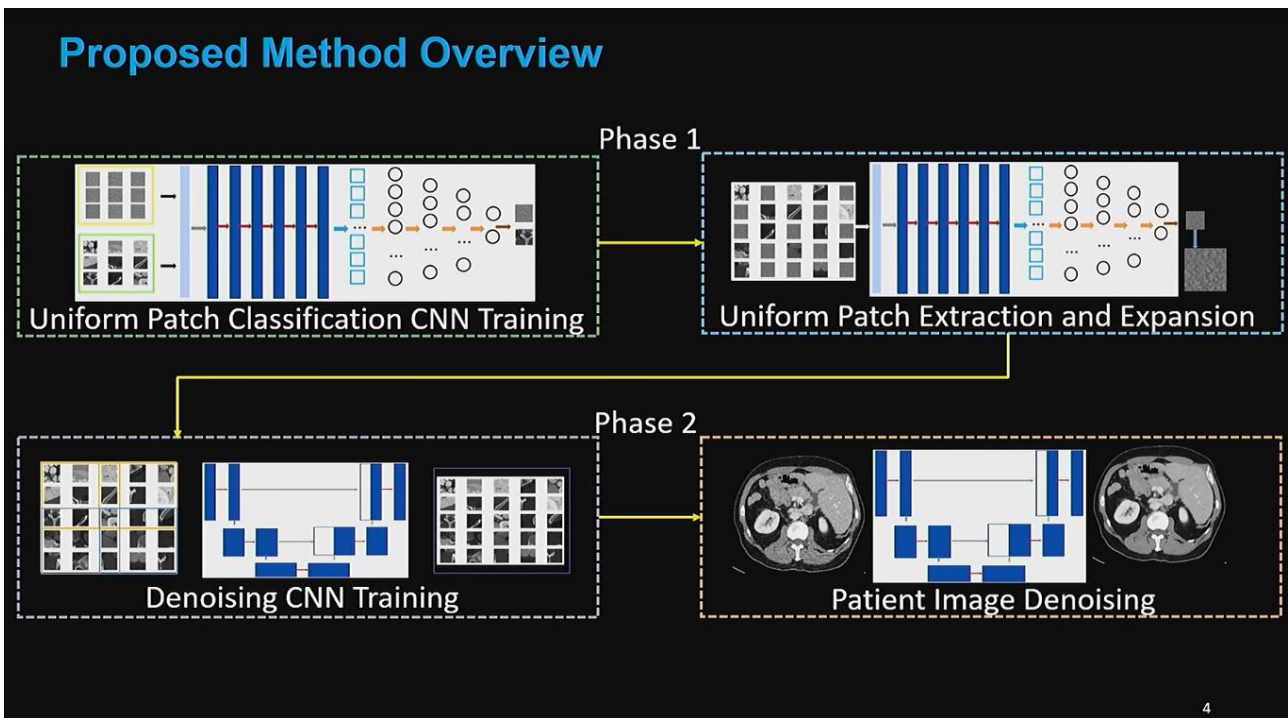
Purpose:

- To develop a training scheme only uses clinical images.
- To apply the training scheme on a single-patient denoising task.

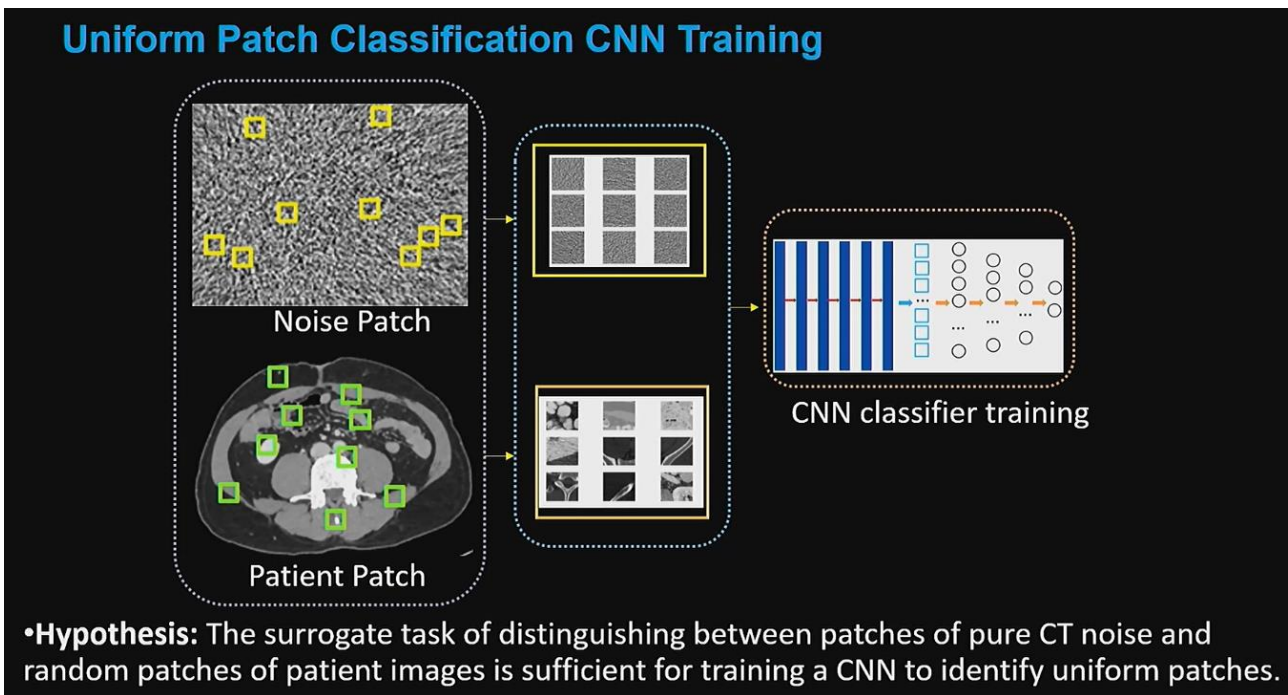


3

圖八、去雜訊深度學習模型自我監督式學習訓練方式 [6]



圖九、去雜訊深度學習模型兩階段式訓練 [6]



圖十、去雜訊深度學習模型使用 Patch 的示意圖 [6]

Motivation

- In dual-source CT, the field of measurement (FOM) of the second source-detector pair is often limited by technical constraints.
- Dual-energy information is only available within the small FOM.
- Deep learning-based iterative reconstruction to recover missing information.

*Note: The reconstruction was performed using a custom reconstruction software. The vendor's reconstruction software would clip the reconstruction to the small FOM.

dkfz.

圖十一、深度學習應用於改善較小可視範圍造成的截斷誤差 [7]

Proposed Approach

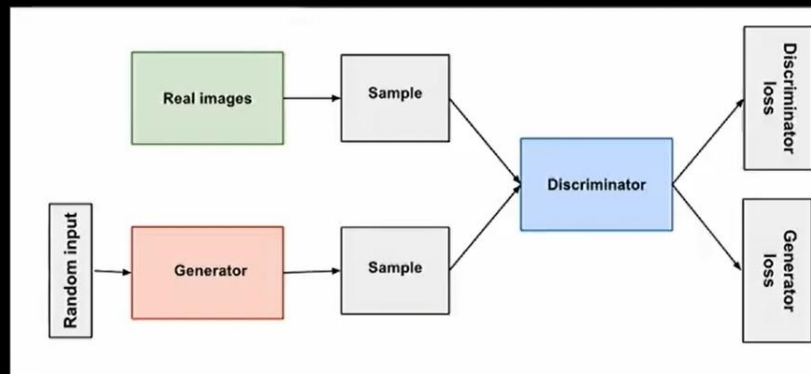
(Training)

Make use of limited angle information outside small FOM to learn a more reliable mapping.

圖十二、深度學習應用於改善較小可視範圍造成的截斷誤差技術架構 [7]

AI approach: Generative Adversarial Network

- Combination of two networks
- Generator
 - Creates artificial image from input
- Discriminator
 - Classifies image as real or generated
- Combined training of two networks to lower generator loss



https://developers.google.com/machine-learning/gan/gan_structure

圖十三、使用生成對抗網路進行衰減校正 [8]

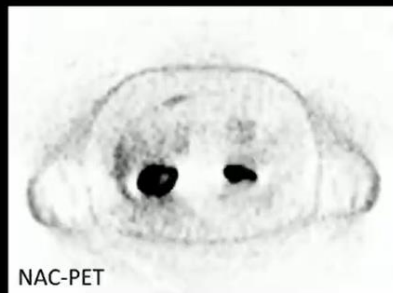
CT-less attenuation for PSMA PET/CT studies

CT scans

NAC PET

AC PET

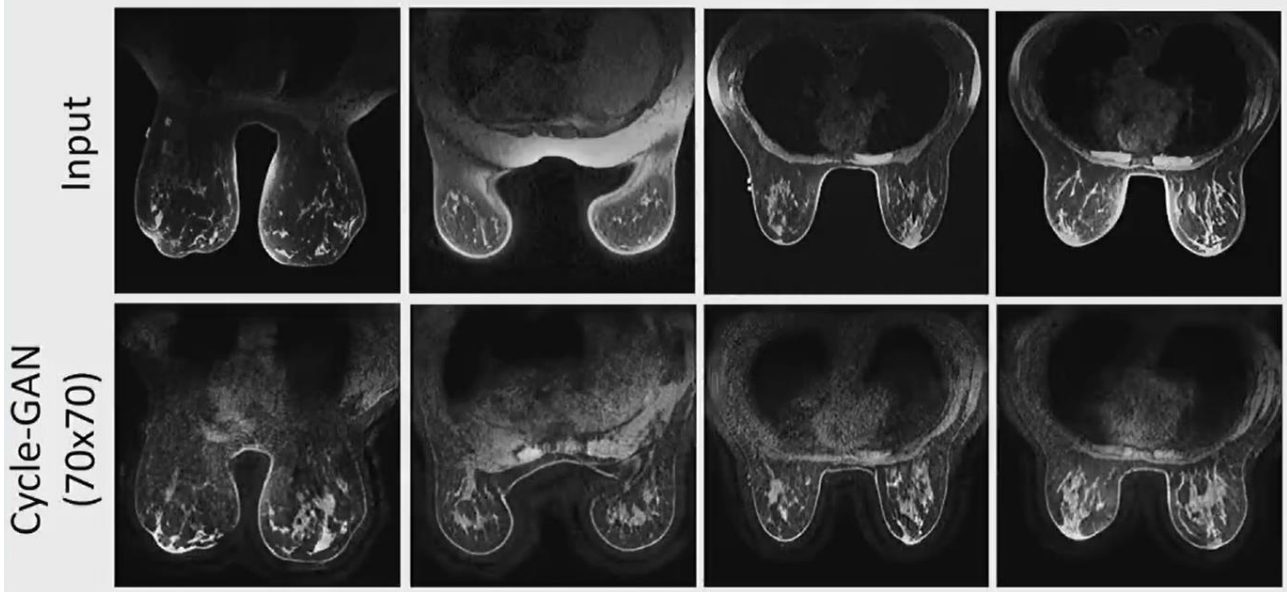
AI-based
AC PET



- 303 PET-CT studies at NCI, NIH
 - ¹⁸F-DCFPyL PSMA
 - Must include:
 - NAC-PET
 - AC-PET
 - CT scans
- Data splits:
 - 183 Training
 - 60 validation
 - 60 testing

圖十四、使用生成對抗網路進行衰減校正的結果 [8]

Cycle GAN transformation (Siemens -> GE)

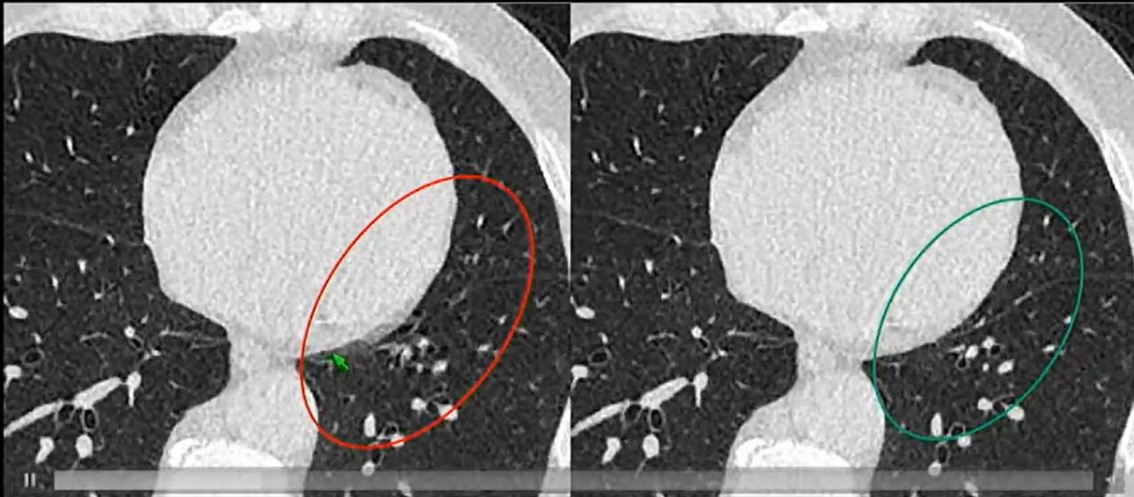


圖十五、使用生成對抗網路轉化不同儀器的造影影像 [9]

Results:

Without MC

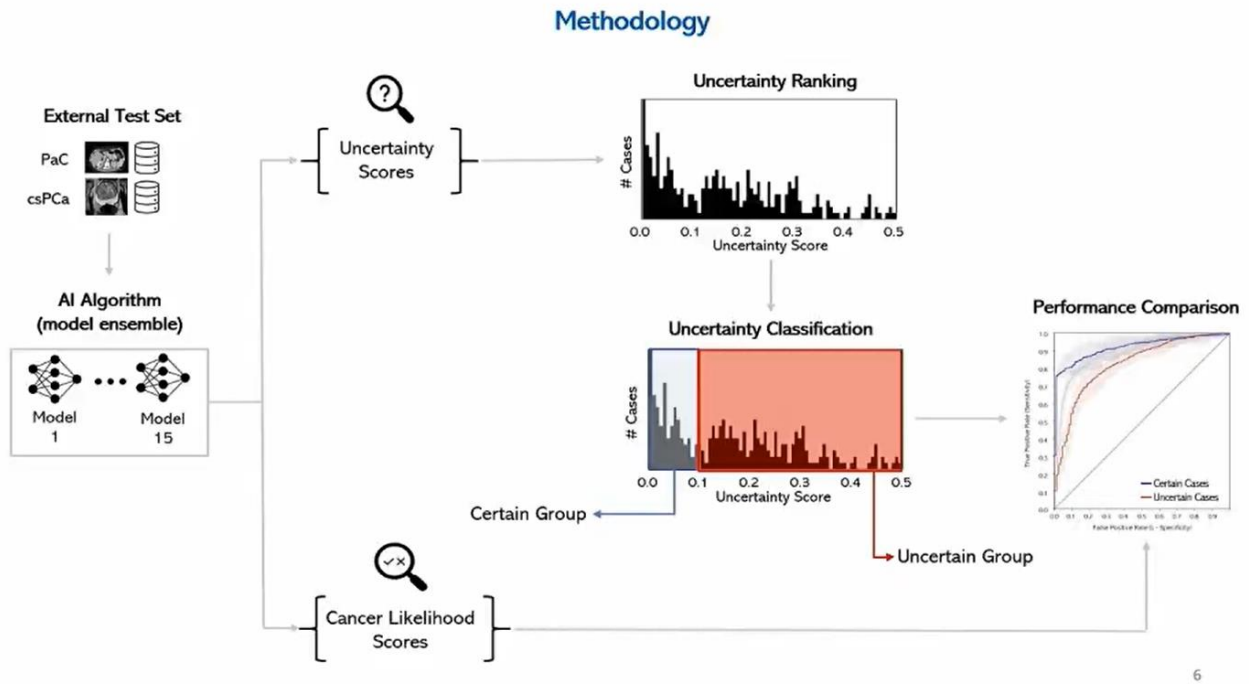
With MC



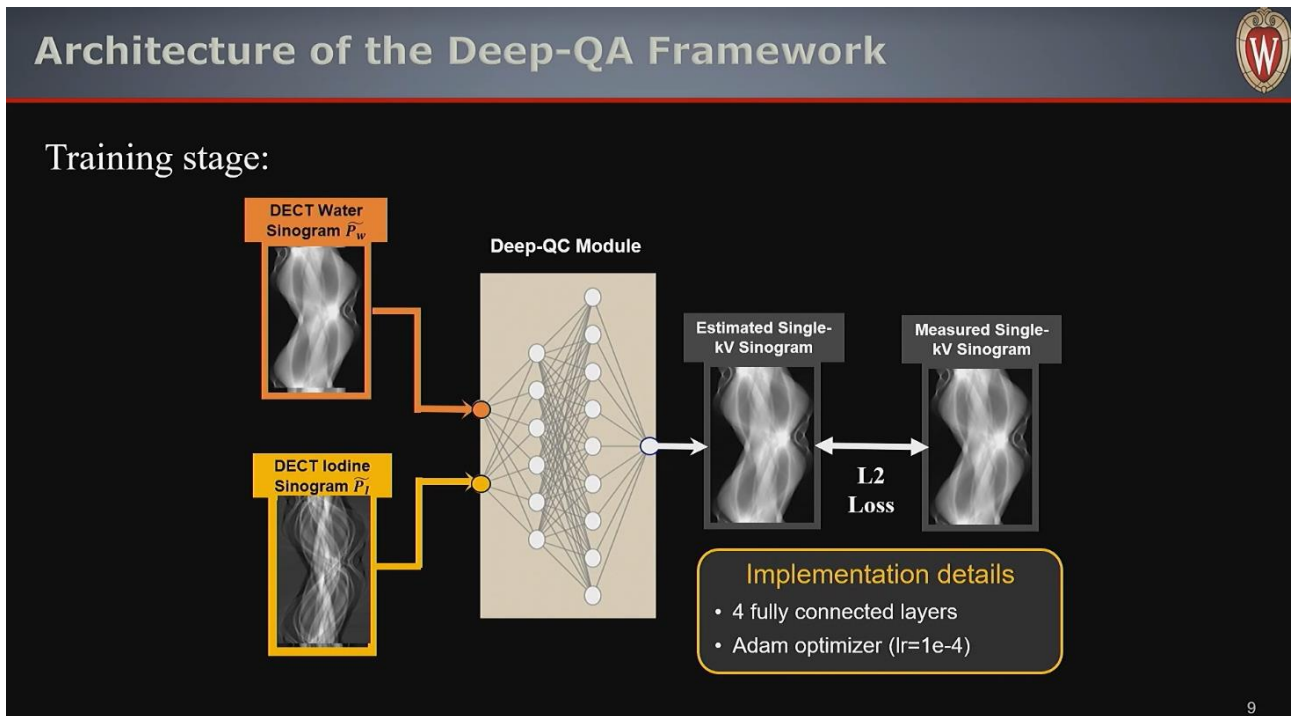
Case 4

14

圖十六、深度學習應用在位移補償 [10]



圖十七、利用整體學習對模型穩定性進行量化 [11]

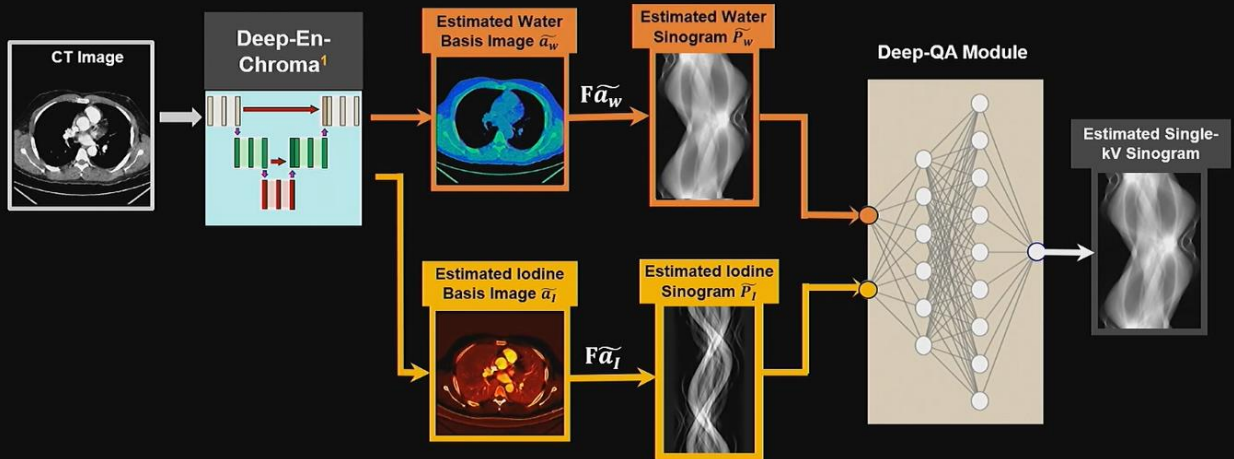


圖十八、使用 Dual-Energy CT 建立品質控制的深度學習網路 [12]

Architecture of the Deep-QA Framework



Inference stage:



* F denotes the forward projection

1. Y. Li, et al, Proc. SPIE, Vol. PC12031, PC120310I (2020)

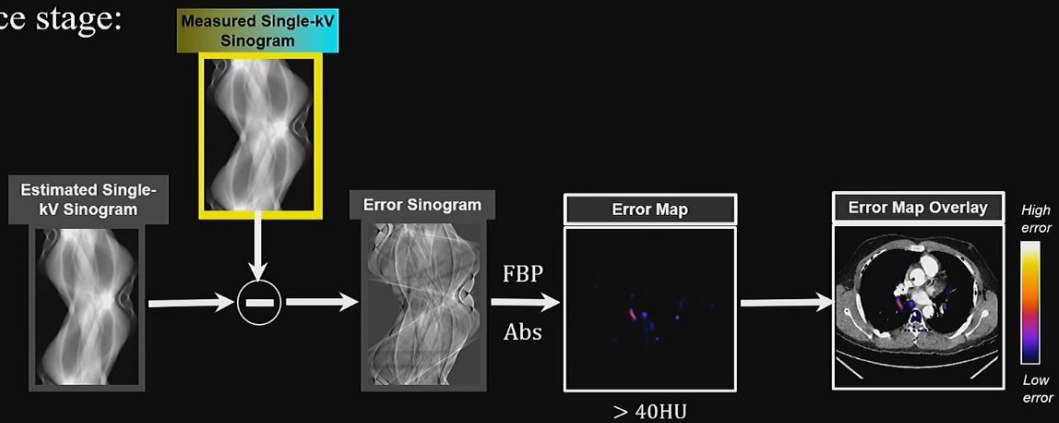
10

圖十九、結合材質解析網路與品質控制網路 [12]

Architecture of the Deep-QA Framework



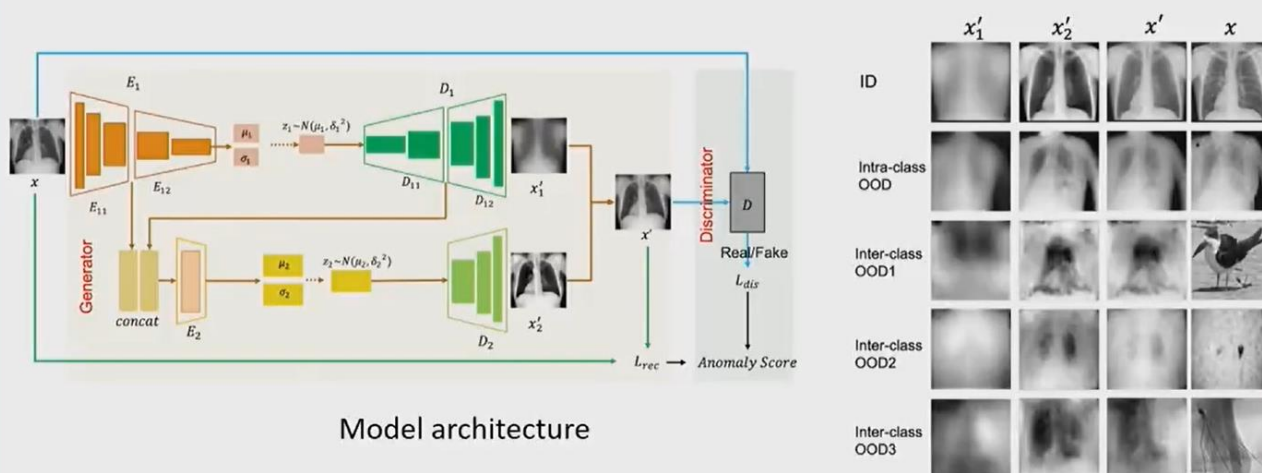
Inference stage:



11

圖二十、利用品質控制網路的誤差作視覺化呈現[12]

CVAD – an unsupervised anomaly detector

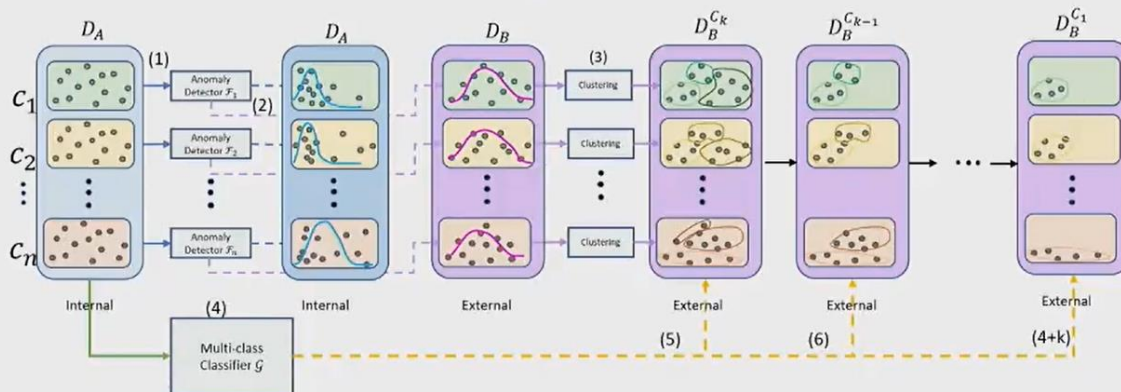


Guo, Xiaoyuan, Judy Wawira Gichoya, Saptarshi Purkayastha, and Imon Banerjee. "CVAD: An Anomaly Detector for Medical Images Based on Cascade VAE." In *Workshop on Medical Image Learning with Limited and Noisy Data*, pp. 187-196. Springer, Cham, 2022.

圖二十一、使用 VAE 搭配生成對抗網路進行非監督式學習訓練 [13]

External Shift Data Identification

MedShift Pipeline

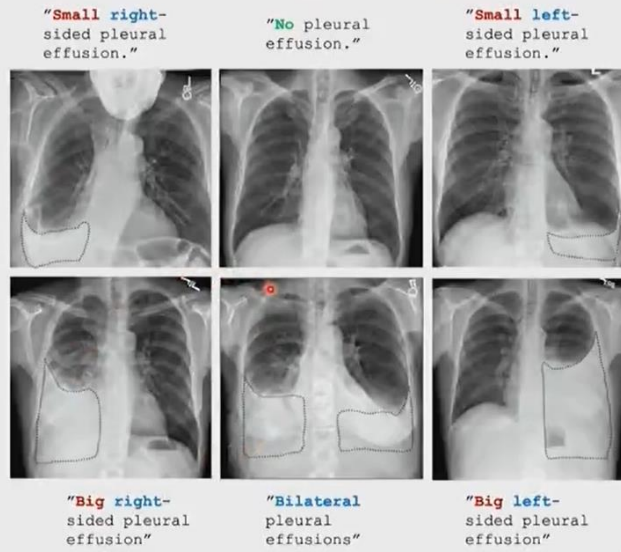


圖二十二、利用數據位移增強模型穩定性的技術架構圖 [13]

RoentGen: Vision-Language Radiology Model

10,000+ A100
GPU hours in
total

~1,500 A100
GPU hours for
final model

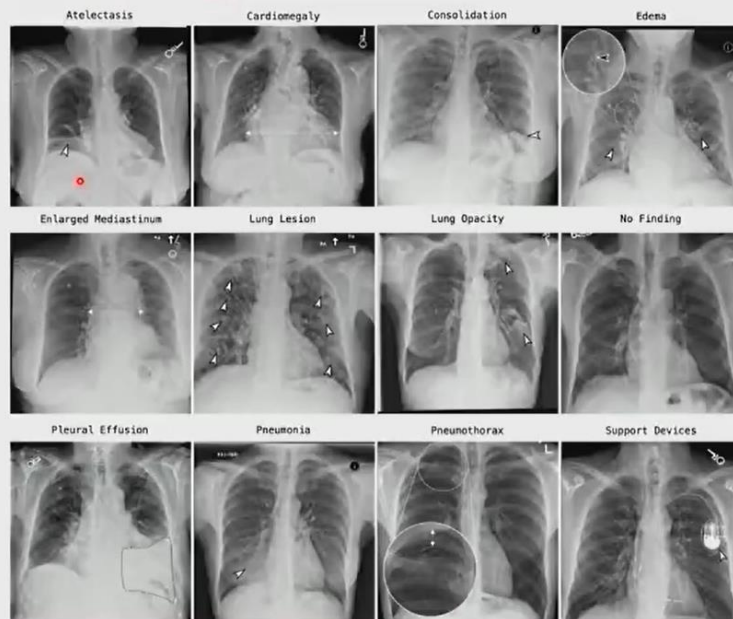


Chambon*, Bluethgen*, et al. RoentGen: Vision-Language Foundation Model for Chest X-ray Generation. arXiv. 2022
Chambon*, Bluethgen*, et al. Adapting Pretrained Vision-Language Foundational Models to Medical Imaging Domains. NeurIPS FMDM 2022



圖二十三、使用擴散模型結合文字與影像(一) [14]

RoentGen Capabilities



- Chambon*, Bluethgen*, et al. RoentGen: Vision-Language Foundation Model for Chest X-ray Generation. arXiv. 2022
- Chambon*, Bluethgen*, et al. Adapting Pretrained Vision-Language Foundational Models to Medical Imaging Domains. NeurIPS FMDM 2022



圖二十四、使用擴散模型結合文字與影像(二) [14]

Five challenges to AI success

- **Acquiring** and normalizing **the right data** from the right sources
- Integrating AI models naturally into clinical workflows
- Scaling AI models to support hundreds of healthcare organizations and thousands of clinicians
- Building continuous improvement into every AI deployment
- Earning the trust of frontline clinicians

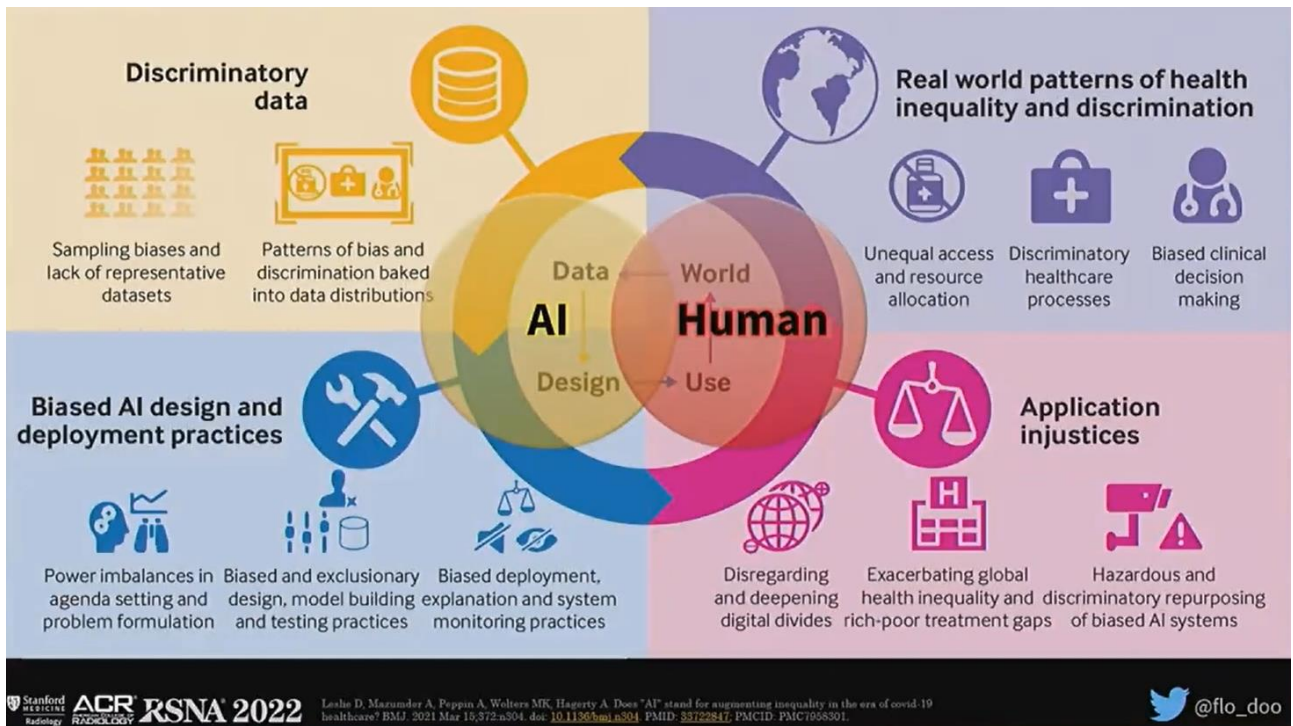
lucemhealth.

圖二十五、AI 成功的五個挑戰 [15]

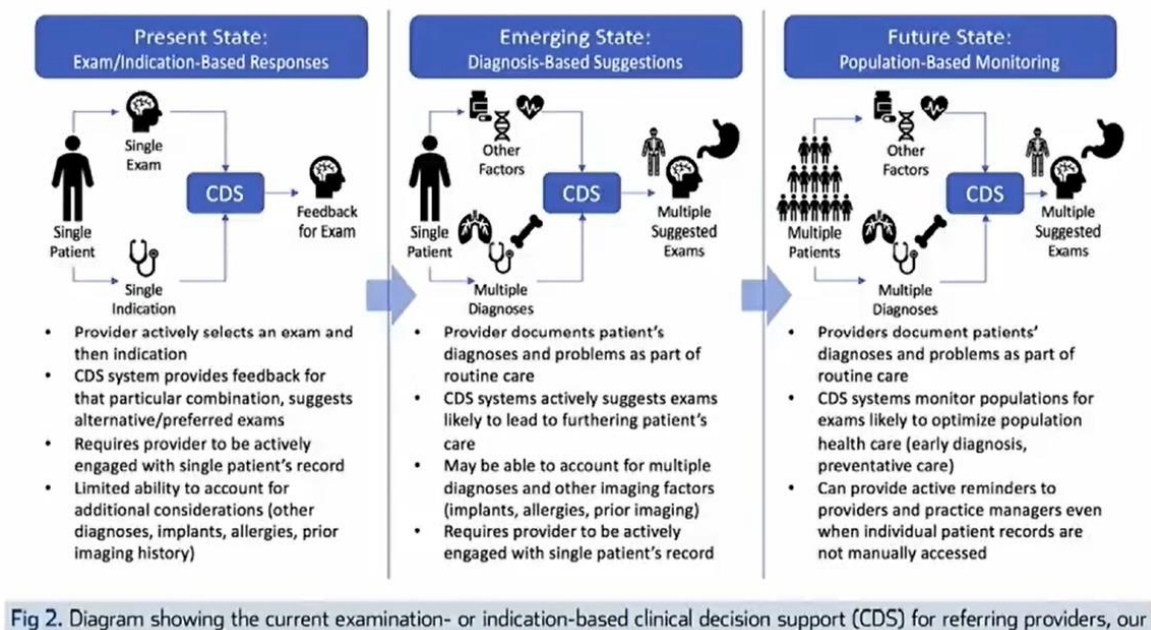
By converting to a Standardized Protocol set ...

- simplifies life for the CT **Radiologist** and **Technologists**
- decreases the burden on the CT **Physicist**
- saves **time and money** for any institution.
- should take full advantage of each **scanner's capabilities**
- provides the required documentation for the **Joint Commission**
- It makes **standardization** of protocols across the enterprise more likely to succeed.

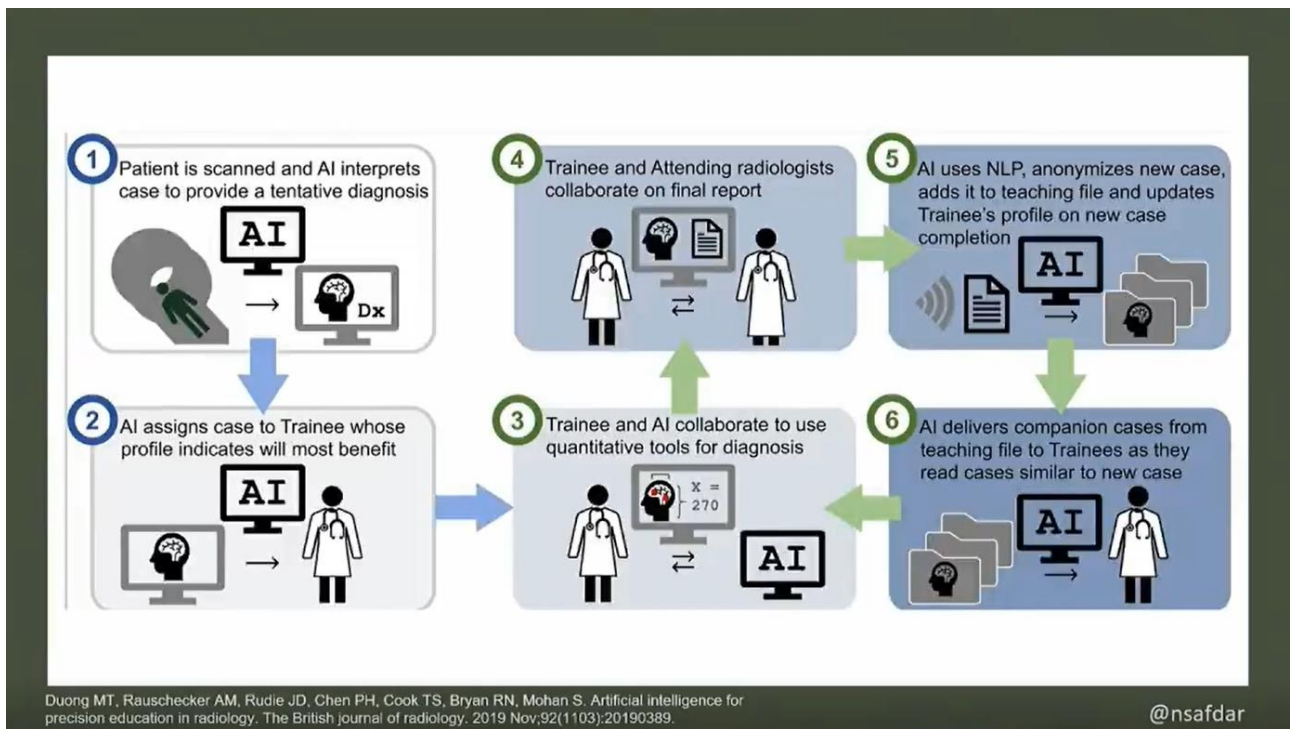
圖二十六、針對 AI 模型制定標準的重要性 [15]



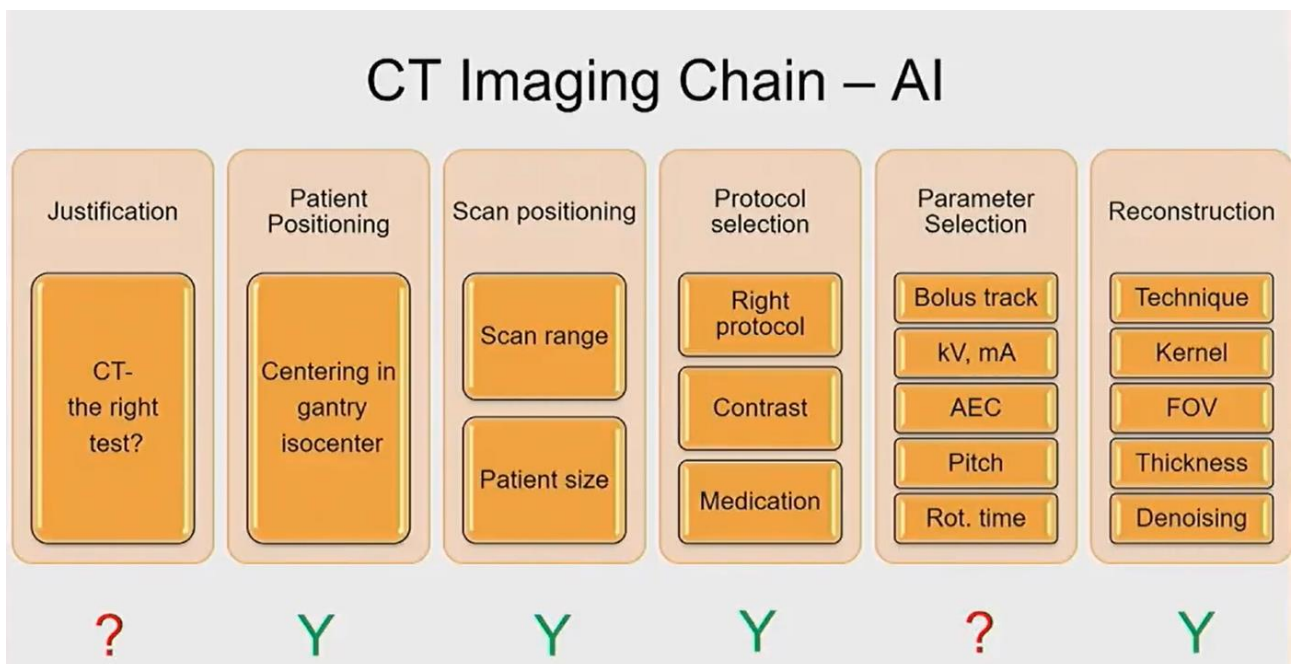
圖二十七、AI 模型落地面臨的機會與挑戰 [16]



圖二十八、臨床決策系統的過去、現在與未來 [17]

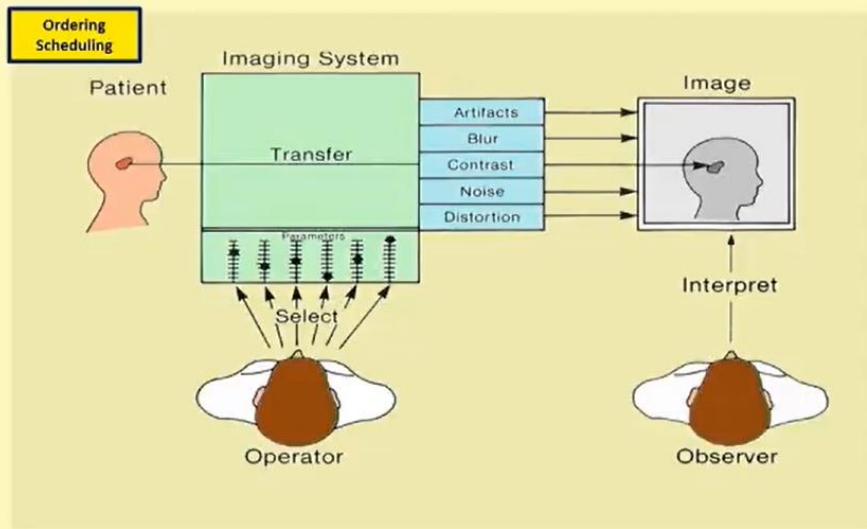


圖二十九、AI 導入臨床工作流程 [17]



圖三十、現有 CT 放射造影鏈 [18]

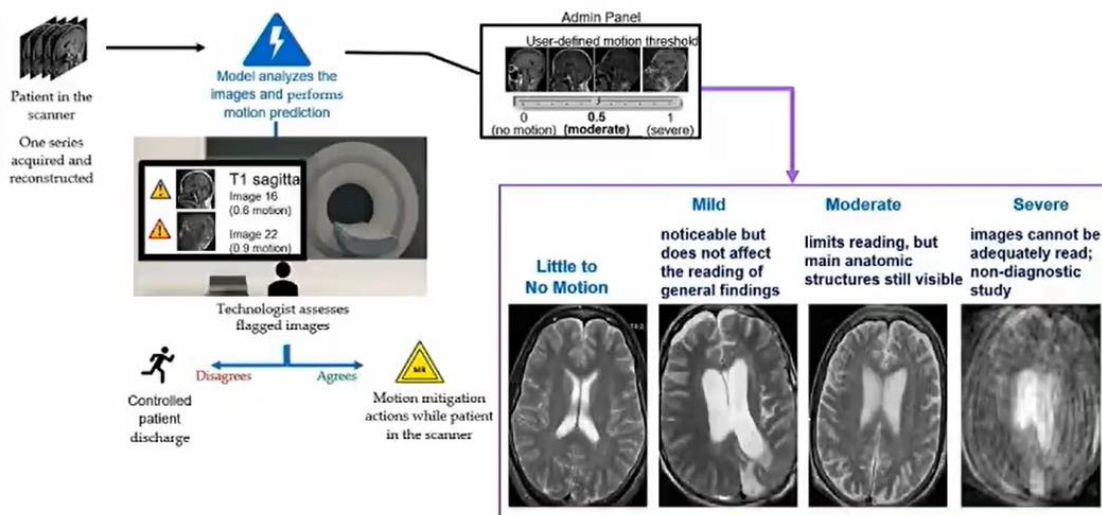
MEDICAL IMAGING CHAIN



圖三十一、醫學影像鏈流程示意圖 [19]

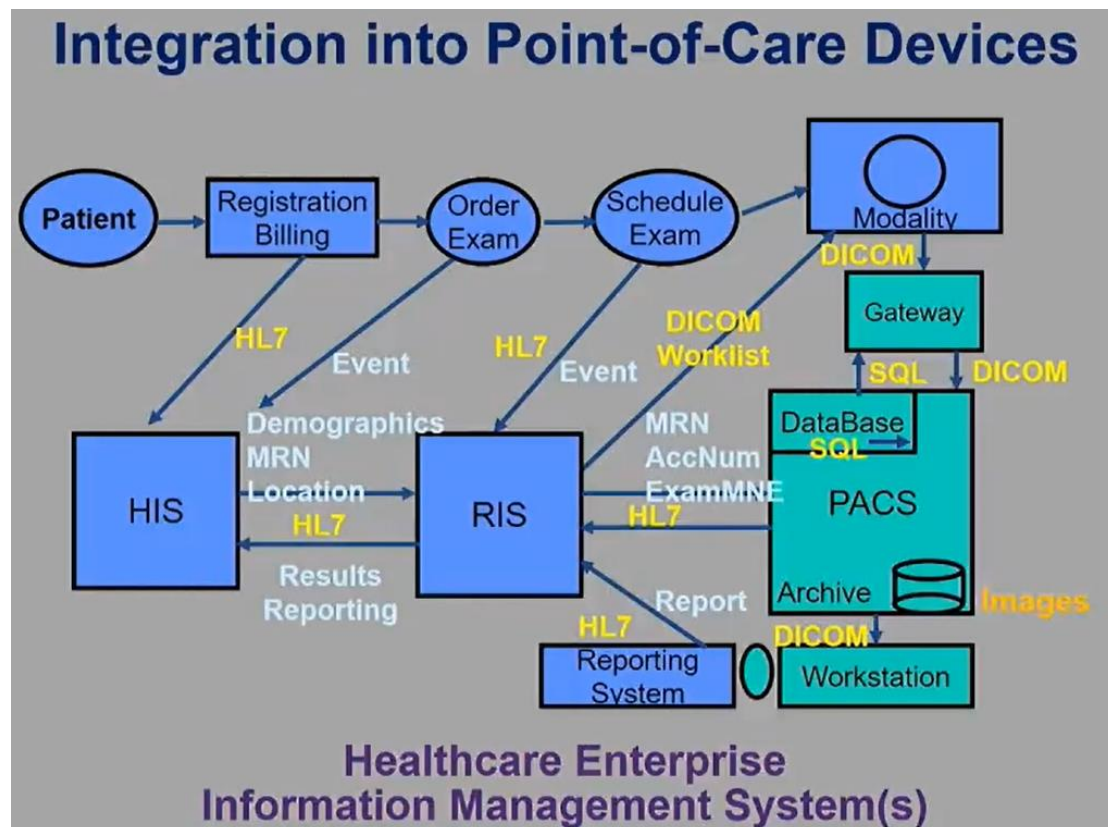
At the Scanner: Image Quality Dashboard

Example Motion Dx on MRI Brain



Slide courtesy of Fabiola Macruz, MD, PhD, Ivana Sesic, MD and Donnella Comeau, MD, PhD

圖三十二、以戰情分析方式呈現整個流程的影像品質 [19]



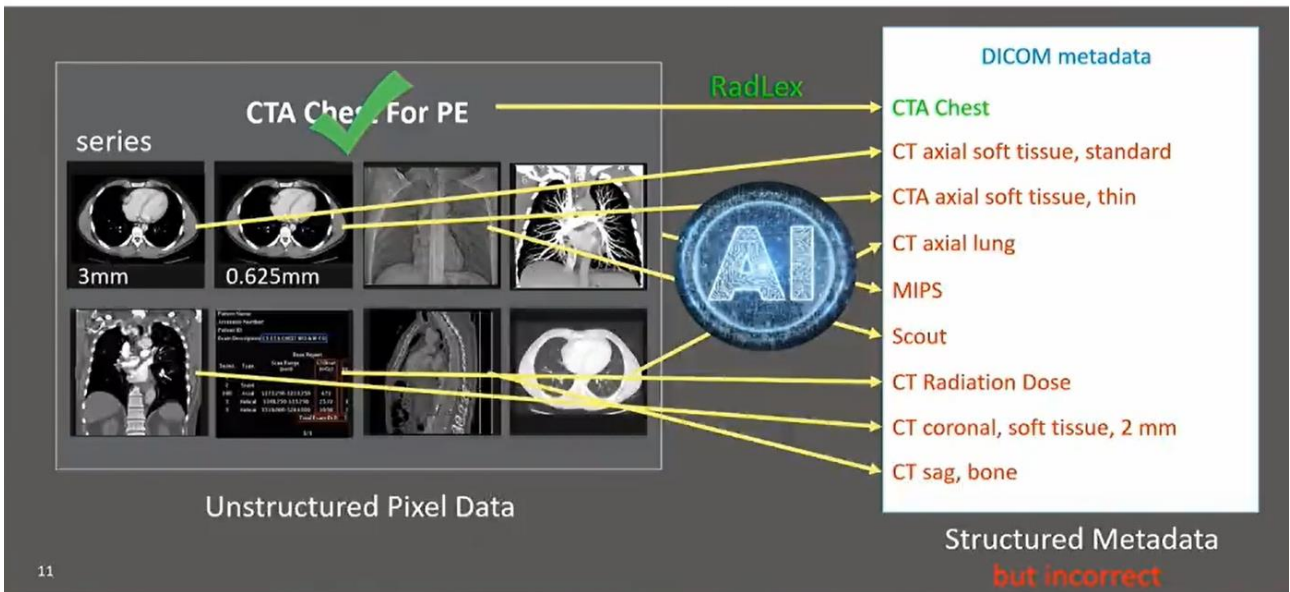
圖三十三、整合至醫療資訊系統的架構圖 [19]

Summary

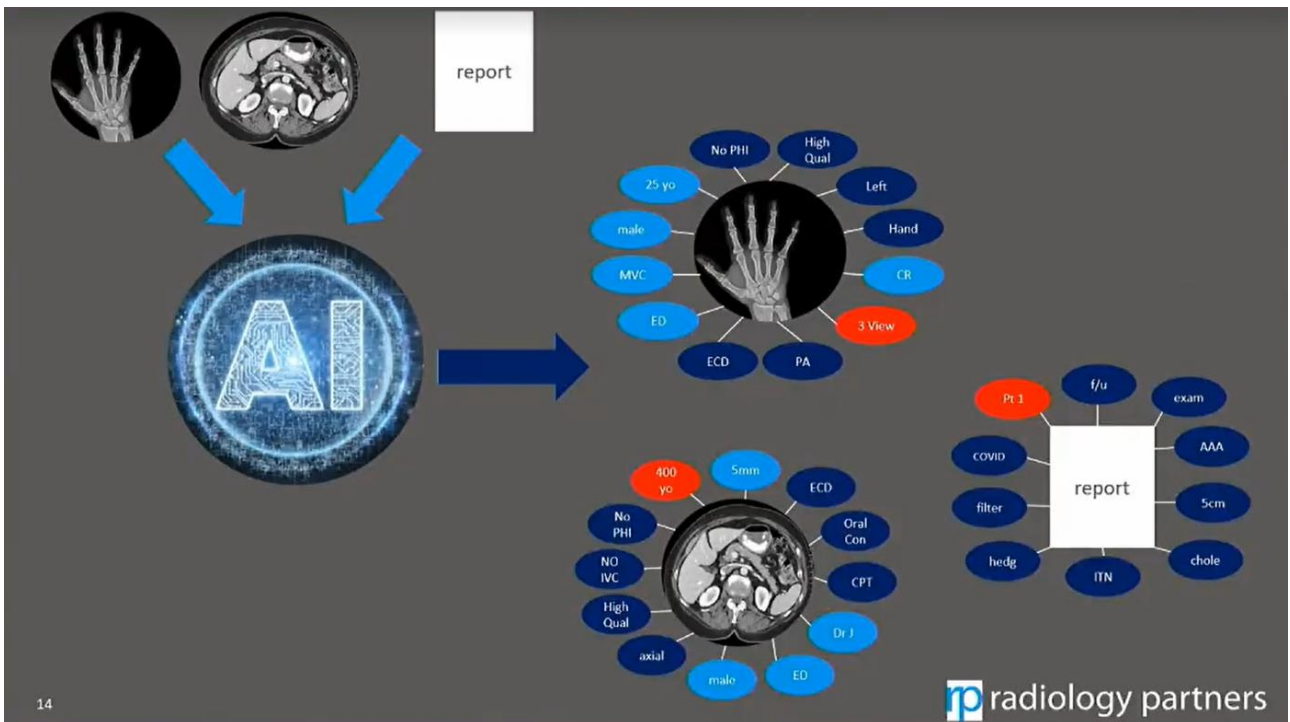
- **AI can be applied at multiple points throughout the medical imaging chain, not just at Diagnosis**
 - Imaging Examination Ordering, Protocoling, Acquisition, Image Quality, Triage and Worklist Prioritization, Image Processing, Hanging Protocols, Displays, Archival Strategies, Use of Images for Research
- **Integration Standards and Orchestration Frameworks must be used to embed AI tools into the clinical workflow**
 - DICOM, HL7 FHIR, IHE, CDE, RadLEX, Docker
- **Platforms and Marketplaces exist to assist in application development & product purchase**
- **RADIOLOGISTS must be involved in ML Model development, performance evaluation and QA as a clinical domain expert**

圖三十四、總結 AI 整合至醫學影像鏈的關鍵 [19]

Because Our Data Is Unstructured...



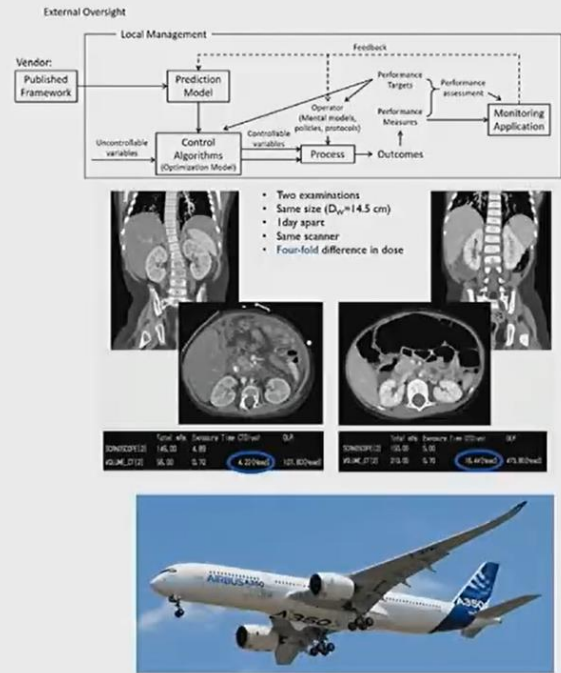
圖三十五、利用 AI 將工作站資訊轉為元數據 [20]



圖三十六、利用 AI 整合不同種類的醫療數據 [20]

Conclusion

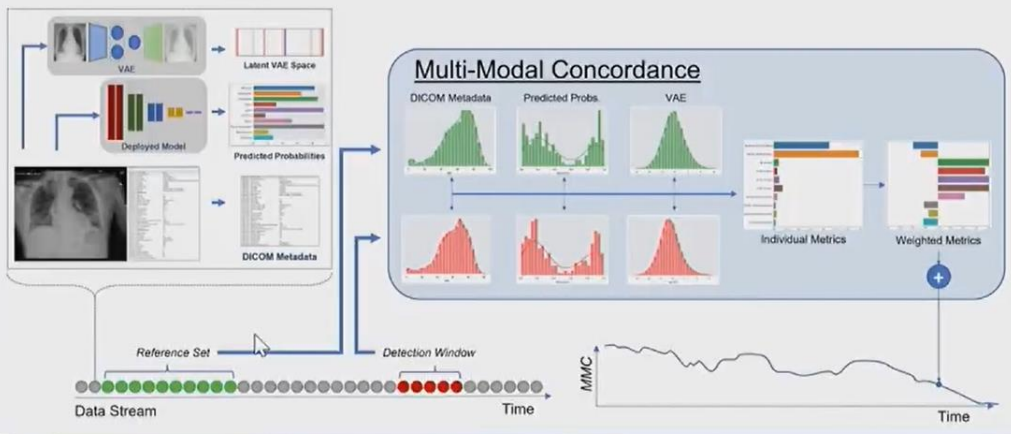
- ▶ Quality can never be assumed
 - Quality must be validated, verified, and monitored
- ▶ Process control is a program
 - Tools must be in place to support the entire program
- ▶ Quality is a philosophy, not just a set of tools
 - Must drive toward continuous quality improvement
- ▶ Quality problems can perpetuate for decades
 - The CT radiation dose problem is still far from solved
- ▶ Certain AI tools might help, but only in the context of a program and after a lot of “boring” QI work
 - Such as image quality-based optimization, monitoring applications, protocol management, etc.
- ▶ Other sectors moved on decades ago
 - It’s time to modernize our tools, modernize our approach



圖三十七、AI 影像品質確保重要性的結論 [21]

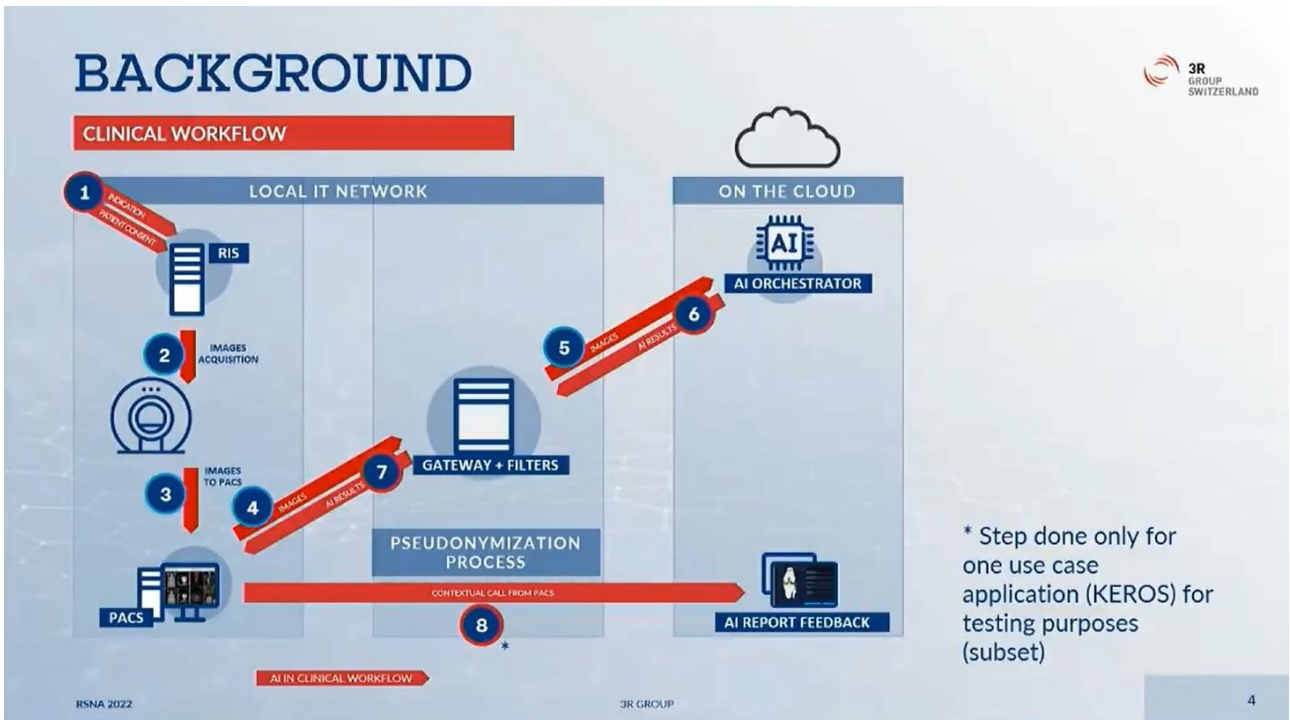
The Future: Automated Monitoring

CheXstray: Real-time Multi-Modal Data Concordance for Drift Detection in Medical Imaging AI

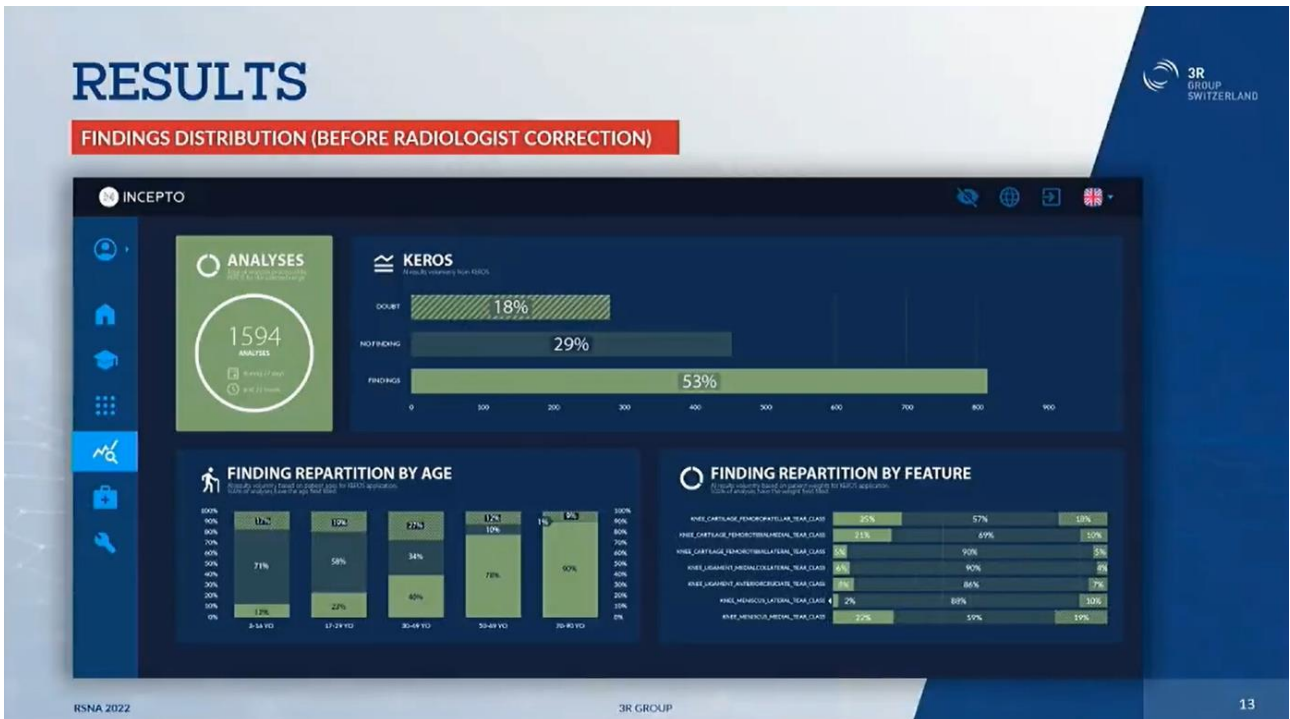


Soin et al. arXiv, 2022.

圖三十八、AI 模型表現的戰情分析 [22]

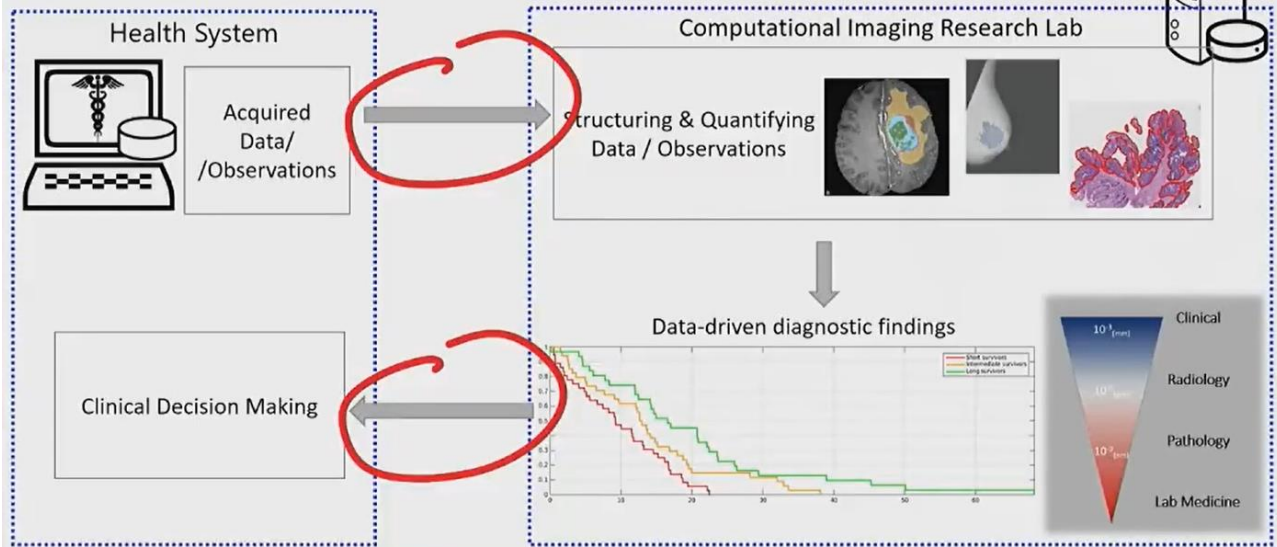


圖三十九、以端雲共生方式實現 AI 臨床工作流程品質確保 [23]



圖四十、以視覺化介面實現數據的即時戰情分析 [23]

Typical Configuration of Translational AI studies



圖四十一、端雲共生方式連接數據與人工智慧 [24]

Take Home Message(s) for Translational Research

TRANSLATIONAL RESEARCH SHOULD CONTRIBUTE TO:

1. Address clinical requirements
2. Support decision-making, towards reducing clinician's burnout
3. Personalized diagnosis driven by population studies

THE NEED

- Assessment of generalizability, by capturing ample patient demographics.
- Addressing bias in AI, and inequities in underserved/underrepresented patient populations.

THE PROMISE:

Federated Learning & Real-World Deployment

(a paradigm shift in multi-site collaborations)

Enables access to Large & Diverse Data

A solution to legal, privacy, & ownership concerns

Performs in par (or even better) to data-sharing

Big data analyses to optimally address clinical questions, even in rare diseases.

Thank you for your attention!

圖四十二、聯邦學習部署流程與展望 [24]

The screenshot shows the Kaggle interface for the 'RSNA 2022 Cervical Spine Fracture Detection' competition. The header includes the Kaggle logo, a search bar, and 'Sign In' and 'Register' buttons. The left sidebar contains navigation options: Create, Home, Competitions, Datasets, Code, Discussions, Learn, and More. The main content area features a competition banner with the title 'RSNA 2022 Cervical Spine Fracture Detection' and a prize of '\$30,000'. Below the banner, there are tabs for Overview, Data, Code, Discussion, Leaderboard, and Rules. The 'Overview' section is expanded, showing a table with the following content:

Description	Goal of the Competition
<p>Evaluation</p> <p>Timeline</p> <p>Prizes</p> <p>Code Requirements</p> <p>Acknowledgements</p>	<p>Over 1.5 million spine fractures occur annually in the United States alone resulting in over 17,730 spinal cord injuries annually. The most common site of spine fracture is the cervical spine. There has been a rise in the incidence of spinal fractures in the elderly and in this population, fractures can be more difficult to detect on imaging due to superimposed degenerative disease and osteoporosis. Imaging diagnosis of adult spine fractures is now almost exclusively performed with computed tomography (CT) instead of radiographs (x-rays). Quickly detecting and determining the location of any vertebral fractures is essential to prevent neurologic deterioration and paralysis after trauma.</p>

圖四十三、RSNA 2022 頸椎骨折偵測人工智慧挑戰賽 [25]

The screenshot shows the Kaggle interface for the 'RSNA Screening Mammography Breast Cancer Detection' competition. The header includes the Kaggle logo, a search bar, and 'Sign In' and 'Register' buttons. The left sidebar contains navigation options: Create, Home, Competitions, Datasets, Code, Discussions, Learn, and More. The main content area features a competition banner with the title 'RSNA Screening Mammography Breast Cancer Detection' and a prize of '\$50,000'. Below the banner, there are tabs for Overview, Data, Code, Discussion, Leaderboard, and Rules. The 'Overview' section is expanded, showing a table with the following content:

Description	Goal of the Competition
<p>Evaluation</p> <p>Timeline</p> <p>Prizes</p> <p>Code Requirements</p>	<p>The goal of this competition is to identify breast cancer. You'll train your model with screening mammograms obtained from regular screening.</p> <p>Your work improving the automation of detection in screening mammography may enable radiologists to be more accurate and efficient, improving the quality and safety of patient care. It could also help reduce costs and unnecessary medical procedures.</p>

圖四十四、RSNA 2023 乳腺癌 X 光檢測人工智慧挑戰賽 [26]

Challenges with AI Deployment

78%¹

of AI/ML projects stall at some stage before deployment

96%¹

of enterprises encounter data quality and labeling challenges

78%³

of facilities can require more than 6 months to deploy an AI solution

81%²

Training the algorithm has proven more challenging than expected

50%²

Report data is not in a usable form, lack people/tools to label

The **most common hurdle** organizations face when deploying AI/ML solutions is around the data used to build and train the models. Companies frequently **misunderstand** or underestimate the data they already have and the utility it provides, how that data needs to be **organized & labeled**, and what data is needed to be acquired to properly build the required models.

As a result, the projects cannot be implemented or are implemented poorly due to various data quality-related issues.

1. Dimensional Research: Artificial Intelligence and Machine Learning Projects are Obstructed by Data issues

2. Dimensional Research: What data scientists tell us about AI model training today

3. Enlitic Sponsored Reaction Data Survey

圖四十五、AI 產品部署落地的調查結果 [27]

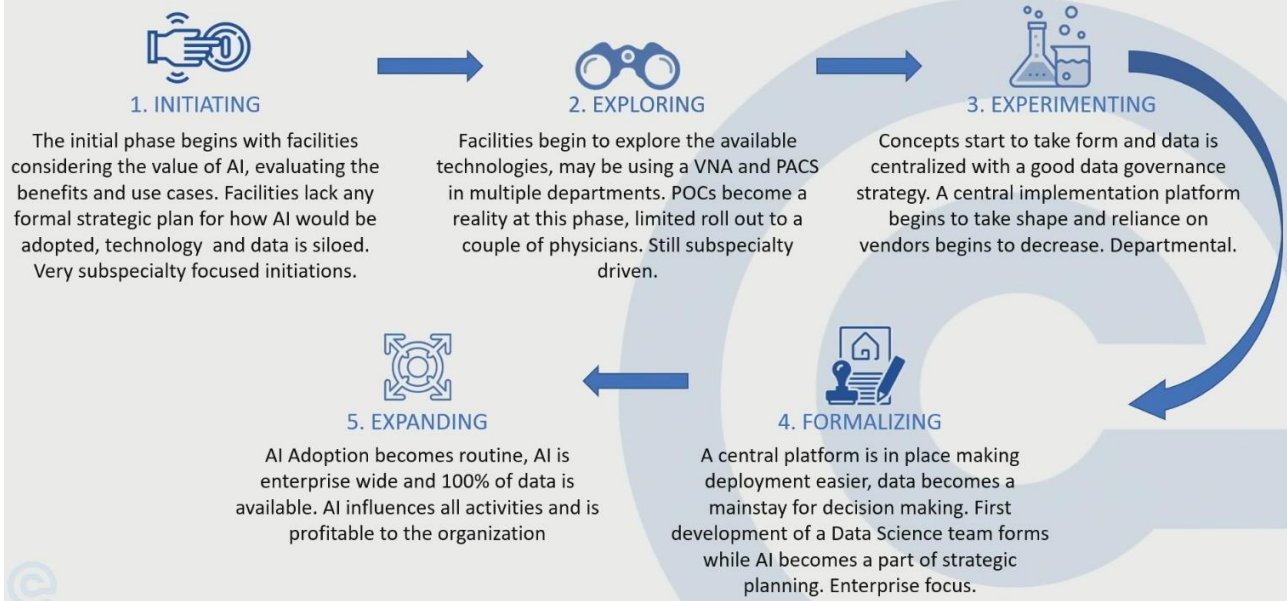
Challenges within Radiology AI

- Radiology data is **highly nuanced** and unintended bias is hard to avoid without proper education.
- Data scientists and engineers need support from **many experts** – not just radiologists.
- More **time is spent building tools** enabling us to build clinical AI than actually building clinical AI.
- Most hospitals do not design **software infrastructure** with “ease of AI integration” in mind.
- Validation is **expensive** but important to repeat for each target population.
- Workflow **integration** needs to be as convenient and non-threatening as possible.
- Adoption requires **buy-in from every stakeholder**, but they all speak different languages.
- [And more...](#)

While businesses are broadly aware of the importance of adopting AI technology, and the advantages it can offer, they **fail to approach it from a strategic standpoint**; this means fully understanding the aims and objectives of all aspects of AI operations, from data gathering to how the insights uncovered are communicated across the workforce and put to work.

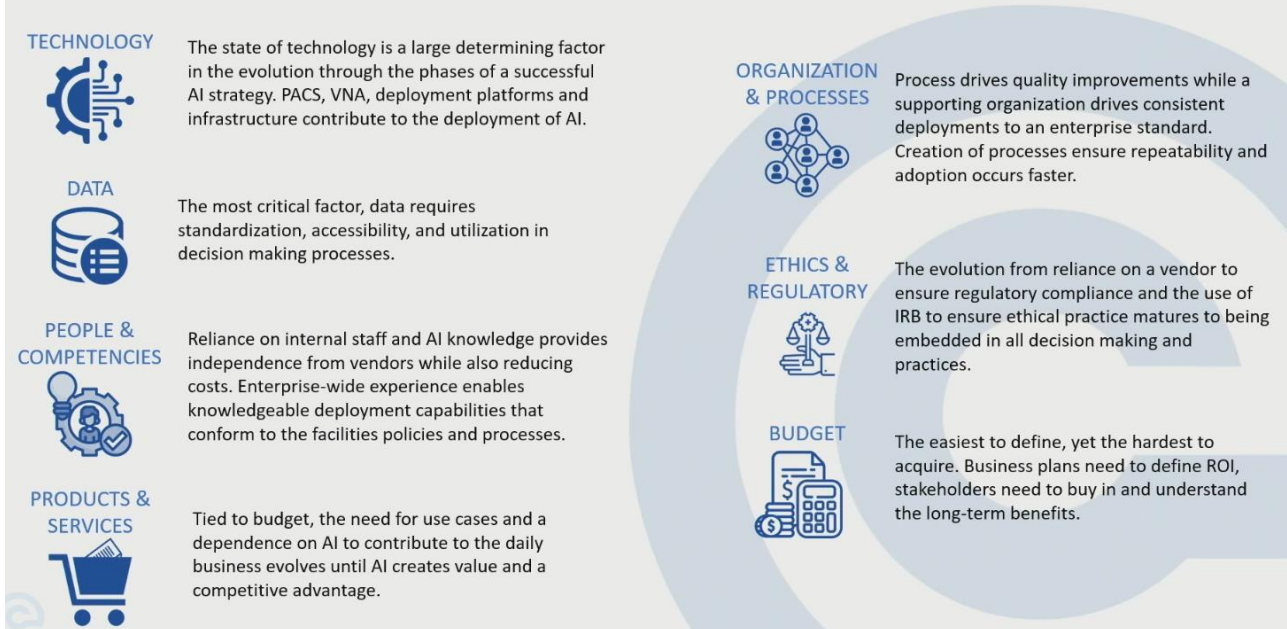
圖四十六、AI 產品部署落地的挑戰 [27]

Phases of Adoption

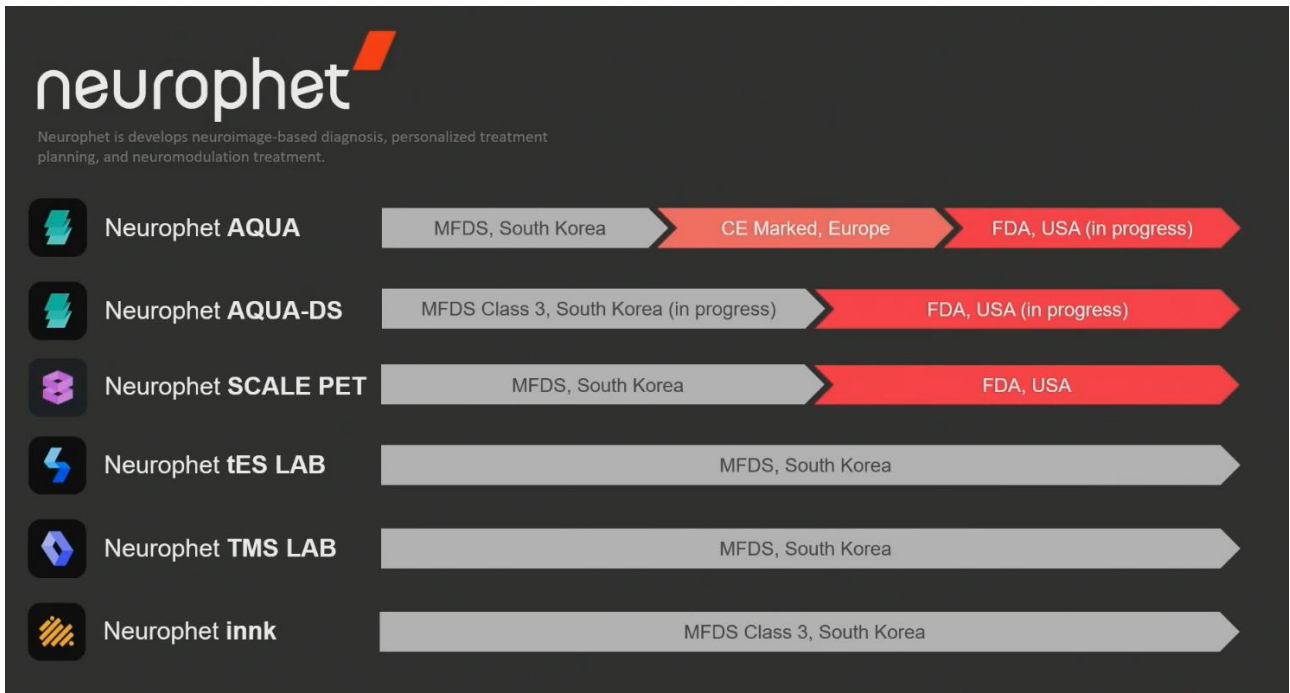


圖四十七、AI 產品流程的各面向 [27]

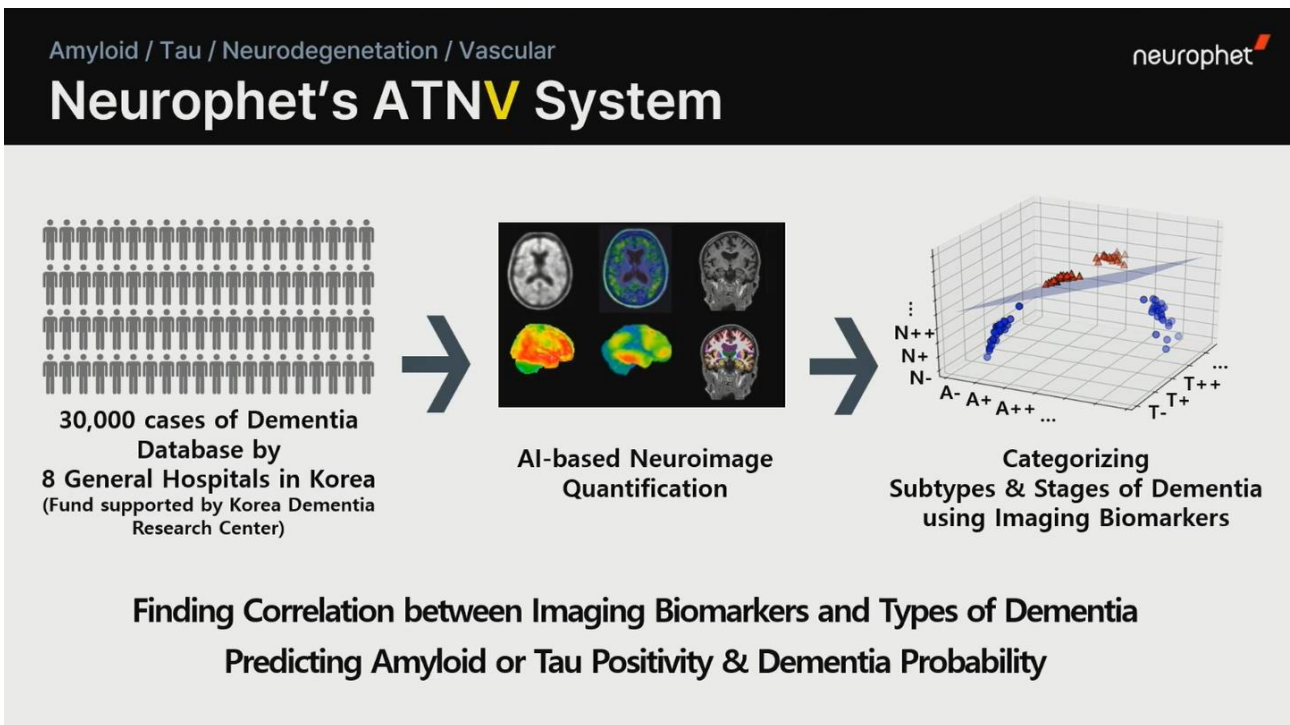
Factors to Consider at Each Phase



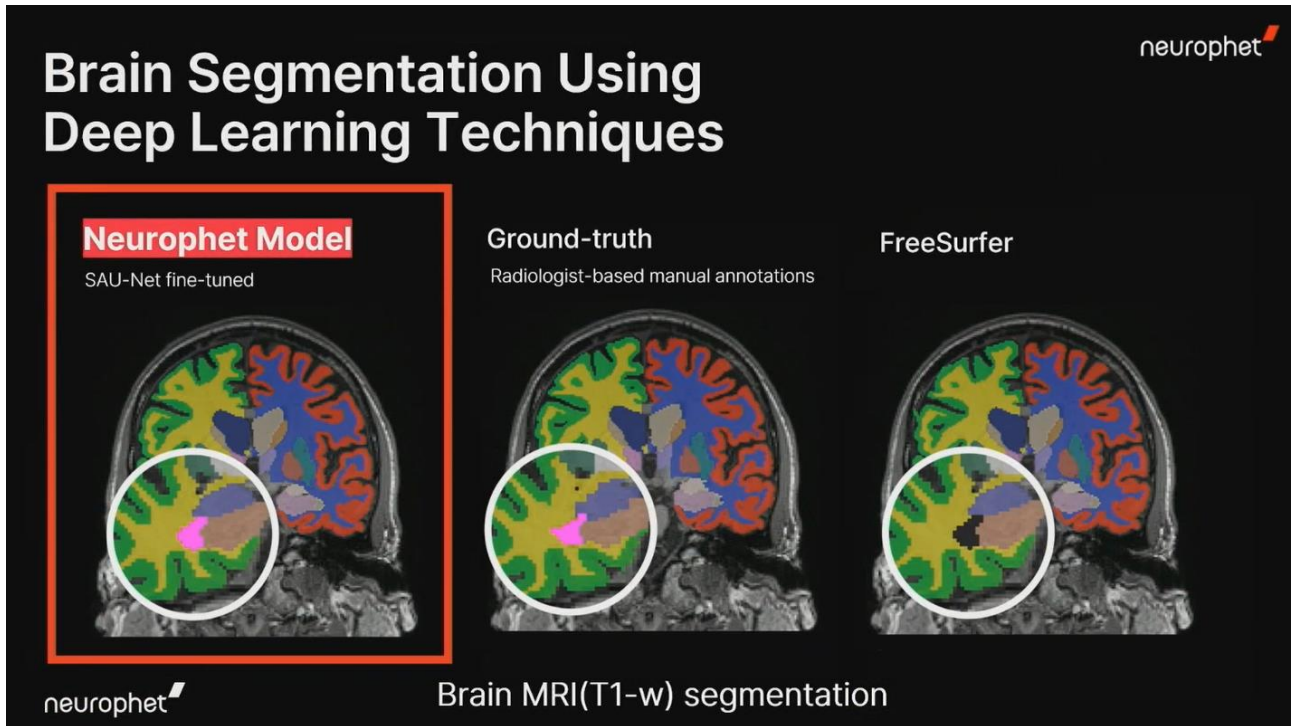
圖四十八、AI 產品在每一個面向該思考的問題 [27]



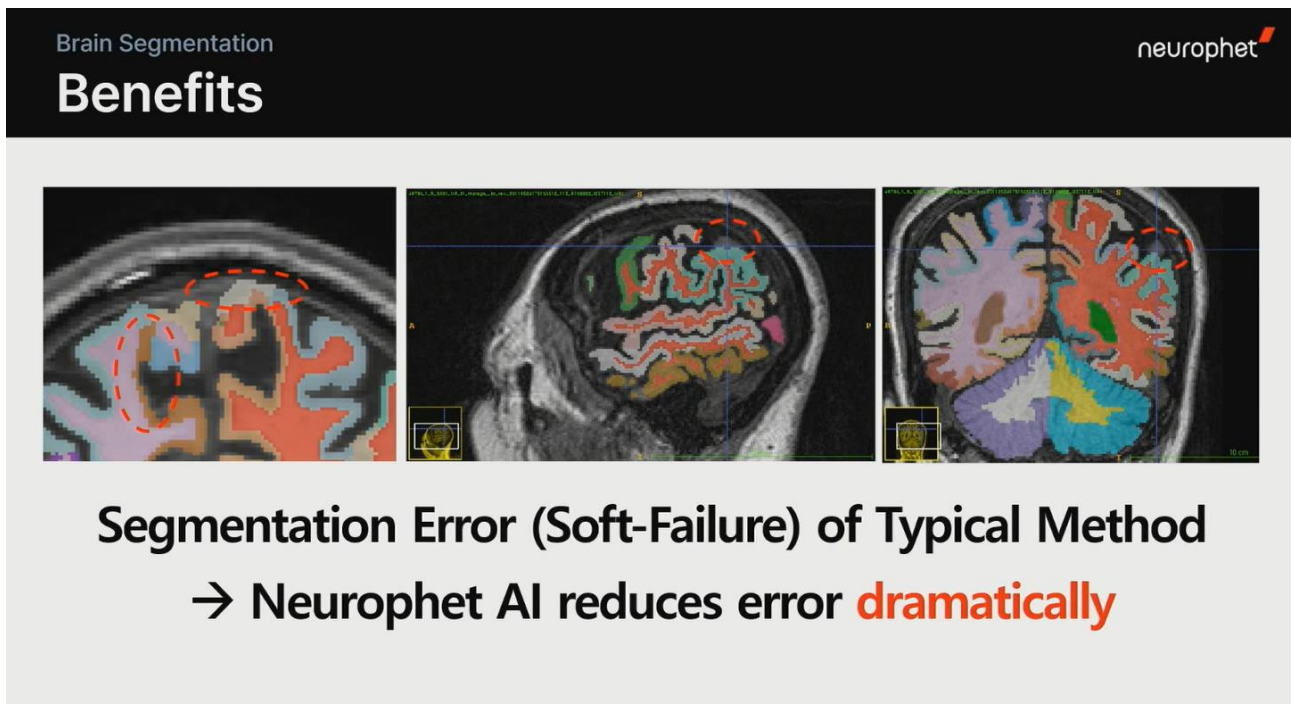
圖四十九、Neurophet 各功能模組於美國 FDA 申請現況 [28]



圖五十、Neurophet 利用大數據建置 AI 腦功能影像分析平台 [28]



圖五十一、MRI 腦功能影像分割深度學習 [28]



圖五十二、使用深度學習進行影像分割的優點 [28]

Benefits

Brain MRI(T1-w) segmentation of multiple brain regions for volume quantification



Neurophet **SegPlus**

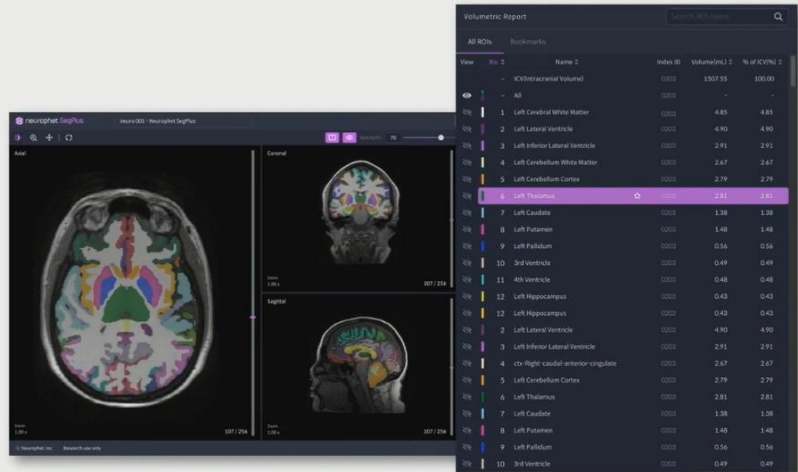
For quick & precise analysis

- ROI segmentation viewer
- A downloadable report of volume quantification

Web-based

Viewer

Data Export

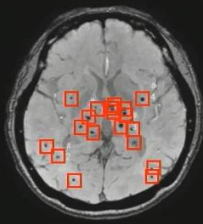


圖五十三、各腦區的計算結果與量化呈現 [28]

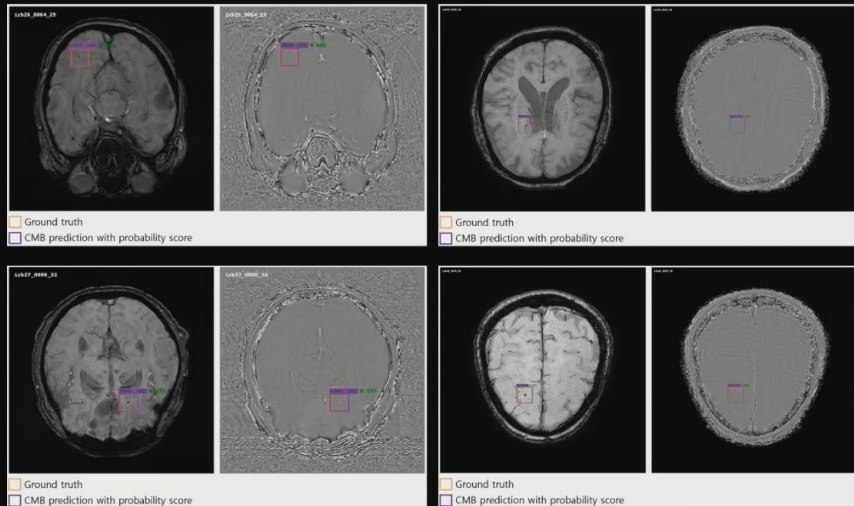
Cerebral Microbleeds Detection

Analysis complete suspected Hemorrhage found

- The Largest Size : 5.34 mm
- Total Counts : 10
- Location : Deep area



CMBs	Region	Probability (%)	The largest size/ total size in radius (mm)
# 1	Basal ganglia	98.56	3mm / 5mm
# 2	Corpus callosum	85.65	2mm / 2mm
# 3	Brain stem	98.65	2mm / 2mm
# 4	Cerebellum	84.54	2mm / 2mm



圖五十四、腦出血影像自動偵測呈現 [28]

六、參 考 文 獻

1. slide from Lifeng Yu, Ph.D., 「 Deep Learning in CT Imaging: Clinical implementation and evaluation 」
2. slide from Guang-Hong Chen, 「 Addressing CT Image Reconstruction Problems via Deep Learning Schemes 」
3. slide from Gong H, 「 Patient-specific uncertainty and bias quantification for deep-learning-based noise reduction in diagnostic x-ray CT 」
4. slide from Yasunori Nagayama, 「 Seeing More with Super-Resolution Deep-Learning CT Reconstruction 」
5. slide from Sen Wang, 「 Spectral CT Image Denoising from Routine Scans using a Noise2Noise Framework 」
6. slide from Wenchao Cao, 「 One-Shot Learning for Patient-Specific CT Image Denoising 」
7. slide from Joscha Maier, 「 Deep Learning-based Iterative Reconstruction for Field of View Extension in Dual-Source Dual-Energy CT 」
8. slide from Baris Turkbey M.D., 「 Artificial Intelligenece in Nuclear Medicine 」
9. slide from Maciej A. Mazurowski, 「 Breast MRI Harmonization 」
10. slide from Qiulin Tang, 「 Deep-learning-based motion compensation for lung CT image reconstruction 」
11. slide from Natalia Alves, 「 Towards Safe Clinical Use of AI for Cancer Detection Through Uncertainty Quantification 」
12. slide from Xin Tie, 「 Deep-QA: a deep quality assurance network for AI in CT applications 」
13. slide from Imon Banerjee, 「 Who is watching the AI: computational solution 」
14. slide from Akshay Chaudhari, 「 Rethinking the Role of Data in Radiology AI 」
15. slide from Myron A. Pozniak, 「 CT Protocol Standardization: the Foundation for Successful AI 」
16. slide from Florence Doo, 「 Failures, Biases, and more: When Good AI Goes Bad 」
17. slide from Nabile M. Safdar, 「 AI for Radiology Workflow: Academic 」
18. slide from Giridhar Dasegowda, 「 Promise and pitfalls of AI in CT Protocols 」
19. slide from Katherine P.Andriole, 「 Applications Throughout the Radiological Imaging Chain 」
20. slide from Nina Kottler, 「 AI for Radiology Workflow: Private Practice 」
21. slide from David B. Larson, 「 A Framework for Quality Control in the Era of AI 」
22. slide from Walter Wiggins, 「 Monitoring Deployed AI Tools 」
23. slide from F.Zanca, 「 Monitoring performance of AI algorithms(A Quality Assurance Experience) 」
24. slide from Spyridon Bakas, 「 Federated Learning & Clinical Deployment 」
25. <https://www.kaggle.com/competitions/rsna-2022-cervical-spine-fracture-detection>
26. <https://www.kaggle.com/competitions/rsna-breast-cancer-detection>
27. slide from David Wilson, 「 5 Steps to Your AI Strategy: Enlitic 」
28. slide from Hye Weon Kim, 「 Quantitative Approach of AI-based Neuroimaging 」

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RSNA 2022



Sun, November 27

Keynote Speaker: Advances in Temporal Bone Imaging Ashok Srinivasan, MD 9:00am-10:00am N229	S1-SSH01-1
Keynote Speaker: Imaging of Myocarditis David M. Biko, MD 9:00am-10:00am S405	S1-SSPD01-6
Photon Counting Shuai Leng, PHD, Ke Li, PhD 9:00am-10:00am E353B	S1-CPH14
Science Session with Keynote: Head and Neck (Temporal Bone) Dann Martin, MD, Ashok Srinivasan, MD 9:00am-10:00am N229	S1-SSH01
↳ Keynote Speaker: Advances in Temporal Bone Imaging Ashok Srinivasan, MD 9:00am-10:00am N229	S1-SSH01-1
Science Session with Keynote: Pediatric Imaging (Chest/Cardiac) David M. Biko, MD, Sarah M. Desoky, MD, Shabnam B. Grover, MD,DMRD 9:00am-10:00am S405	S1-SSPD01
↳ Keynote Speaker: Imaging of Myocarditis David M. Biko, MD 9:00am-10:00am S405	S1-SSPD01-6

Sun, November 27

Translational AI Science: Bringing Advances in Deep Learning into Clinical Mariam S. Aboian, MD, PhD, Spyridon Bakas, PhD, Charles E. Kahn, MD, MS, M... 9:00am-10:00am E350	S1-RCP32
Deep Learning Lab: DICOM Data Wrangling with Python Katherine P. Andriole, PhD 10:30am-11:30am Learning Center - DL	DLL01
Keynote Speaker Eva M. Fallenberg, MD, PhD 10:30am-11:30am E450B	S2-SSBR01-1
Keynote Speaker Francois Benard, MD 10:30am-11:30am E352	S2-SSNMMI01-5
Science Session with Keynote: Breast Imaging (Contrast Enhanced and Vascular Calcifications) Maxine S. Jochelson, MD, Ritse M. Mann, MD, PhD 10:30am-11:30am E450B	S2-SSBR01
↳ Keynote Speaker Eva M. Fallenberg, MD, PhD 10:30am-11:30am E450B	S2-SSBR01-1

RSNA 2022



Sun, November 27

Science Session with Keynote: Nuclear Medicine/Molecular Imaging Francois Benard, MD, Katherine A. Zukotynski, FRCPC, PhD 10:30am-11:30am E352	S2-SSNMMI01
↳ Keynote Speaker Francois Benard, MD 10:30am-11:30am E352	S2-SSNMMI01-5
The Business of Medical Imaging AI Peter Chang, MD, John V. Crues, MD, Andrew D. Smith, MD, PhD, Hari Trivedi, M... 10:30am-11:30am S401	S2-CIN09
5 Steps to Your AI Strategy: Enlitic David Wilson 11:00am-11:15am AI Showcase, South Hall, Level 3	IS2-AI102
Enabling Lung Cancer Screening with iBiopsy? AI-based Software as a Device: Median Technologies Benoit Huet, Science Director, Yan Liu, Chief Medical Officer 11:30am-11:45am AI Showcase, South Hall, Level 3	IS3-AI103
Deep Learning Lab: Data Processing & Curation for Deep Learning Kirti Magudia, MD, PhD, Walter F. Wiggins, MD, PhD 12:00pm-1:00pm Learning Center - DL	DLL02

Sun, November 27

MEDIP-enabled medical image digital twinning in NVIDIA OMNIVERSE: IP Soon Ho Yoon, MD, PhD 12:00pm-12:15pm AI Showcase, South Hall, Level 3	IS4-AI104
Dual- and Multi-energy CT of the Abdomen and Pelvis Bari Dane, MD, Joel G. Fletcher, MD, Cynthia H. McCollough, PhD, Alvin C. Silva... 1:00pm-2:00pm S401	S4-CGI06
Keynote Speaker Helen R. Nadel, MD 1:00pm-2:00pm N226	S4-SSNMMI02-5
Keynote Speaker Susan E. Sharp, MD 1:00pm-2:00pm N226	S4-SSNMMI02-6
Radiology AI Innovation: Academics vs Industry Mona Flores, MD,MBA, Rowland O. Illing, BMBCh, FRCR, Nickolas Papanikolaou... 1:00pm-2:00pm E450A	S4-CIN27
Science Session with Keynote: Nuclear Medicine/Molecular Imaging Helen R. Nadel, MD, Susan E. Sharp, MD 1:00pm-2:00pm N226	S4-SSNMMI02
↳ Keynote Speaker Helen R. Nadel, MD 1:00pm-2:00pm N226	S4-SSNMMI02-5



Sun, November 27

- ↳ Keynote Speaker
Susan E. Sharp, MD
1:00pm-2:00pm
N226 S4-SSNMI02-6
- Artificial Intelligence in Radiology: Managing Professionalism Challenges by RSNA Professionalism Committee)**
Tessa S. Cook, MD, PhD, Kate Hanneman, MD, FRCPC, Ryan K. Lee, MD, Geof...
2:30pm-3:30pm
E451B S5-RCP35
- Gastrointestinal Imaging (Advances in CT Techniques and Dose Reduction)**
Bari Dane, MD, Andrea Ferrero, PhD
2:30pm-3:30pm
S401 S5-SSGI04
- How AI-based CT Denoising Impacts Imaging Workflow Efficiency: An at Tubingen University Hospital: ClariPi, Inc.**
Saif Afat, MD
2:30pm-2:45pm
AI Showcase, South Hall, Level 3 IS9-AI109
- Imaging Informatics (AI and NLP in Reports)**
Gian Marco Conte, MD, PhD, Jessica G. Fried, MD
2:30pm-3:30pm
E350 S5-SSIN01
- Science Session with Keynote: Pediatric Imaging (Neuroradiology)**
Elka Miller, MD, Susan Palasis, MD
2:30pm-3:30pm
S405 S5-SSPD02

Sun, November 27

- State of the Art Coronary CT**
Kristopher W. Cummings, MD, Jonathan Weir-McCall, MBChB, FRCR, Michelle C...
2:30pm-3:30pm
N227B S5-CCA04
- How Structured Intelligence Creates Better Outcomes for All: Kailo Medical**
Bernard Duscher, Robert Newman
3:30pm-3:45pm
Innovation Theater, South Hall A, Level 3 IS8-IT110
- President's Address and Opening Session**
4:00pm-5:30pm
Arie Crown S6-PL01



Mon, November 28

- Artificial Intelligence in Abdominal Imaging**
Imon Banerjee, Errol Colak, MD, Tessa S. Cook, MD, PhD, Brett Marinelli, MD, MS...
8:00am-9:00am
N228 M1-CGI12
- Cutting Edge (Artificial Intelligence)**
9:00am-9:30am
Learning Center Theater M1-STCE
- AI: Intelligent Clinical Neuroimaging On the Horizon**
Daniel S. Chow, MD, Christopher G. Filippi, MD, Mai-Lan Ho, MD, Yvonne W. Lui...
9:30am-10:30am
E352 M3-CNR10
- Gastrointestinal Imaging (Dual- and Multi-energy CT in GI Imaging)**
Jennifer W. Uyeda, MD, Benjamin M. Yeh, MD
9:30am-10:30am
S406B M3-SSGI05
- Keynote Speaker**
Baris Turkbey, MD
9:30am-10:30am
S402 M3-SSNMI03-5
- Keynote Speaker**
Jonathan G. Goldin, MBChB, PhD
9:30am-10:30am
N226 M3-SSCH03-1
- Science Session with Keynote: Chest Imaging (ILD/Emphysema)**
Jonathan G. Goldin, MBChB, PhD, James F. Gruden, MD
9:30am-10:30am
N226 M3-SSCH03

Mon, November 28

- ↳ Keynote Speaker
Jonathan G. Goldin, MBChB, PhD
9:30am-10:30am
N226 M3-SSCH03-1
- Science Session with Keynote: Nuclear Medicine/Molecular Imaging Learning)**
Michael V. Knopp, MD, PhD, Baris Turkbey, MD
9:30am-10:30am
S402 M3-SSNMI03
- ↳ Keynote Speaker
Baris Turkbey, MD
9:30am-10:30am
S402 M3-SSNMI03-5
- Cutting Edge (Photon Counting CT)**
10:00am-10:30am
Learning Center Theater M3-STCE
- Deep Learning Lab: Accessing Freely Available Public Datasets from The Imaging Archive (TCIA)**
Justin Kirby
10:30am-11:30am
Learning Center - DL DLL05
- No Cancer Missed - Next-Generation AI for Breast Cancer Screening:**
Pierre Fillard, PhD
10:30am-10:45am
AI Showcase, South Hall, Level 3 IM1-AI101



Mon, November 28

- New Modeling Approaches for Radiology AI**
Akshay Chaudhari, PhD, Maciej A. Mazurowski, MS, PhD, Valentina Pedoia, PhD...
11:00am-12:00pm
E451B M4-CIN21
- Deep Learning Lab: MedNIST Exam Classification with MONAI**
Bradley J. Erickson, MD, PhD, Jayashree Kalpathy-Cramer, MS, PhD, Kuan Zhan...
12:00pm-1:00pm
Learning Center - DL DLL06
- Cutting Edge (Artificial Intelligence)**
12:15pm-12:45pm
Learning Center Theater M5A-STCE
- The New Role of Lung CT in ILD and Lung Cancer Detection: Quantifying Predicting Disease: contextflow**
Georg Langs, Prof., PhD
12:30pm-12:45pm
AI Showcase, South Hall, Level 3 IM5-AI105
- Deep Learning Lab: CT Body Part Classification**
Ross W. Filice, MD, Ish A. Talati, MSc
1:30pm-2:30pm
Learning Center - DL DLL07
- Physics (AI Applications in CT)**
Grace J. Gang, PHD, Marc Kachelriess, PhD
1:30pm-2:30pm
S404 M6-SSPH05
- Cutting Edge (Photon Counting CT)**
2:30pm-3:00pm
Learning Center Theater M7-STCE

Mon, November 28

- Deep Learning Lab: Basics of NLP in Radiology**
Gurvant Chaudhari, BS, Timothy L. Chen, Jae Ho Sohn, MD
3:00pm-4:00pm
Learning Center - DL DLL03
- Imaging Quality Control in the Era of Artificial Intelligence**
Giridhar Dasegowda, MBBS, David B. Larson, MD, MBA, Myron A. Pozniak, MD
3:00pm-4:00pm
S401 M7-CIN12
- Neuroimaging for Healthy Aging : Diagnosis and Prognosis using AI: Inc.**
Hye Weon Kim, MD
3:00pm-3:15pm
AI Showcase, South Hall, Level 3 IM10-AI110
- Recent Advances in PET/MRI and PET/CT Imaging**
Thomas Beyer, PhD, Ciprian Catana, MD, PhD
3:00pm-4:00pm
S405 M7-CPH07
- Science Session with Keynote: Nuclear Medicine/Molecular Imaging (The**
Donna J. Cross, PhD, Peter Herscovitch, MD
3:00pm-4:00pm
S402 M7-SSNMMI04
- Reimagining AI within the radiology workflow: annalise.ai**
Matthew P. Lungren, MD
3:30pm-3:45pm
AI Showcase, South Hall, Level 3 IM11-AI111
- AI Theater: RSNA AI Challenge**
Speaker TBD
4:00pm-5:00pm
AI Showcase, South Hall, Level 3 IM12-AI112



Mon, November 28

- Developing a System-Wide Imaging Capital Plan: Strategies and Innovative (Sponsored by the Associated Sciences Consortium)**
Jason Newmark, BA,MBA, Peter St John, Sandra A. Strycker, BS, Michelle M. Wa...
4:30pm-5:30pm
N230B M8-CAS01

Tue, November 29

- Emergency (Emergency and Trauma Imaging I)**
Reffy Nicola, DO, Claire K. Sandstrom, MD
8:00am-9:00am
E450A T1-SSER01
- Science Session with Keynote: Pediatric Imaging**
Leah E. Braswell, MD, Summer L. Kaplan, MD, MS
8:00am-9:00am
E353C T1-SSPD03
- Cutting Edge (Artificial Intelligence)**
9:00am-9:30am
Learning Center Theater T1-STCE
- Artificial Intelligence in Pediatric Radiology**
Safwan Halabi, MD, Marla Sammer, MD, Alex Towbin, MD
9:30am-10:30am
E353C T3-CPD09
- Imaging Informatics (AI in Abdominal Imaging)**
Kirti Magudia, MD, PhD, Hari Trivedi, MD
9:30am-10:30am
E451B T3-SSIN03
- Cutting Edge (Photon Counting CT)**
10:00am-10:30am
Learning Center Theater T3-STCE
- Deep Learning Lab: YOLO-Bounding Box Segmentation & Classification 1)**
Bradley J. Erickson, MD, PhD, Pouria Rouzrokh, MD, MPH
10:00am-11:00am
Learning Center - DL DLL09



Tue, November 29

ASRT@RSNA: Leading Medical Imaging Like a Start-Up Ryan Duggan 11:00am-12:00pm N230B	T4-CRT06
Navigate Measure Realize: Three Key Steps To A Successful AI Strategy: Ben Panter, PhD 11:00am-11:15am AI Showcase, South Hall, Level 3	IT2-AI102
Cutting Edge (Long COVID) 12:15pm-12:45pm Learning Center Theater	T5A-STCE
Cutting Edge (Artificial Intelligence) 12:45pm-1:15pm Learning Center Theater	T5B-STCE
Deep Learning Lab: Best Practices for Model Training: Architectures, & Optimization Peter Chang, MD 1:00pm-2:00pm Learning Center - DL	DLL11
Cutting Edge (Molecular Imaging) 1:30pm-2:00pm Learning Center Theater	T6-STCE
Neuroradiology (Brain: Vascular [Excluding Acute Stroke] Stroke [Diagnosis Treatment]) Michele H. Johnson, MD, Mahmud Mossa-Basha, MD 1:30pm-2:30pm E350	T6-SSNR08

Tue, November 29

Understanding and Communicating Artificial Intelligence: Reading, Writing Reviewing Ross W. Filice, MD, John Mongan, MD, PhD, Linda Moy, MD 1:30pm-2:30pm E451B	T6-CIN02
Cutting Edge (Photon Counting CT) 2:30pm-3:00pm Learning Center Theater	T7-STCE
AI Isn't Just for Diagnosis: Example Applications Throughout the Imaging Chain Katherine P. Andriole, PhD, Nina E. Kottler, MD, MS, Nabile M. Safdar, MD, MPH... 3:00pm-4:00pm N226	T7-CIN11
Protocol Optimization for Low Dose CT Lakshmi Ananthakrishnan, MD, Timothy P. Szczykutowicz, PhD, Lawrence N. Tan... 4:30pm-5:30pm N227B	T8-CPH11
Who Is Watching The AI? MLOps for Radiology AI in Production Imon Banerjee, Bernardo C. Bizzo, MD, PhD, Nina E. Kottler, MD, MS, Walter F. W... 4:30pm-5:30pm E451B	T8-CIN22



Wed, November 30

Innovations in Dual and Multi-Energy CT Megan C. Jacobsen, PhD, Daniele Marin, MD, Wei Zhou, PhD 8:00am-9:00am N227B	W1-CPH02
Failures, Biases, and more: When Good AI Goes Bad Florence X. Doo, MD, MA, Hari Trivedi, MD, Paul H. Yi, MD 9:30am-10:30am S401	W3-CIN23
Imaging Informatics (AI and Image Processing) Bernardo C. Bizzo, MD, PhD, Peter A. Harri, MD 9:30am-10:30am E353B	W3-SSIN05
Science Session with Keynote: Breast Imaging (Breast Screening with vRad) Rudolf M. Pijnappel, MD, PhD, Steven P. Poplack, MD 9:30am-10:30am E451B	W3-SSBR08
Deep Learning Lab: YOLO-Bounding Box Segmentation & Classification 2) Bradley J. Erickson, MD, PhD, Pouria Rouzrokh, MD, MPH 10:00am-11:00am Learning Center - DL	DLL12
Cutting Edge (Artificial Intelligence) 10:30am-11:00am Learning Center Theater	W3-STCE
Increase Cardiac CT Productivity with AI: Circle Cardiovascular Imaging Michael F. Morris, MD 10:30am-10:45am AI Showcase, South Hall, Level 3	IW1-AI101

Wed, November 30

Big Data for QI Patricia Balthazar, MD, Neena Kapoor, MD, Ronilda Lacson, MD, PhD 11:00am-12:00pm S401	W4-CIN17
AI-enhanced Detection and Tracking of Cerebral Aneurysms: RapidAI Jeremy J. Heit, MD, PhD 11:30am-11:45am AI Showcase, South Hall, Level 3	IW3-AI103
Deep Learning Lab: Building Custom Deep Learning Models with PyTorch Felipe C. Kitamura, MD, PhD, Ian Pan, MD 11:30am-12:30pm Learning Center - DL	DLL13
The Power of Opportunistic Detection using AI: Qure.ai Rohit Ghosh, Chief Strategy Officer, Imad Nijim, Chief Information Officer, vRad 12:00pm-12:15pm AI Showcase, South Hall, Level 3	IW4-AI104
Cutting Edge (Molecular Imaging) 12:15pm-12:45pm Learning Center Theater	W5A-STCE
Cutting Edge (Photon Counting CT) 12:45pm-1:15pm Learning Center Theater	W5B-STCE
Deep Learning Lab: DICOM In, DICOM Out for Segmentation Thomas W. Loehfelm, MD, PhD 1:00pm-2:00pm Learning Center - DL	DLL14



Wed, November 30

- AI Governance in Medical Imaging: How to Herd the Cats and Avoid Chaos**
Paul J. Chang, MD, Jeevesh Kapur, FRCR,MMed, Marc D. Kohli, MD
1:30pm-2:30pm
S401 W6-CIN08
- Cutting Edge (Artificial Intelligence)**
1:30pm-2:00pm
Learning Center Theater W6-STCE
- Cutting Edge (Photon Counting CT)**
2:30pm-3:00pm
Learning Center Theater W7-STCE
- Keynote Speaker: Technology Advances for Chest CT**
Cynthia H. McCollough, PhD
3:00pm-4:00pm
S501 W7-SSCH07-1
- Physics (X-ray, Fluoro, and Tomosynthesis)**
Hilde Bosmans, PhD, Zhihua Qi, PhD
3:00pm-4:00pm
S403A W7-SSPH09
- Science Session with Keynote: Chest Imaging (Advances in Imaging)**
Myrna C.B. Godoy, MD, PhD, Baskaran Sundaram, MRCP, FRCP
3:00pm-4:00pm
S501 W7-SSCH07
- Keynote Speaker: Technology Advances for Chest CT**
Cynthia H. McCollough, PhD
3:00pm-4:00pm
S501 W7-SSCH07-1

Wed, November 30

- The AI Revolution in MSK: Hot Topics**
John V. Crues, MD, David B. Larson, MD, MBA, Michael L. Richardson, MD, Nav...
4:30pm-5:30pm
E451A W8-CMK12



Thu, December 1

- Artificial Intelligence & Machine Learning in CV Imaging**
Alex K. Bratt, MD, Carlo N. De Cecco, MD, Albert Hsiao, MD, PhD
8:00am-9:00am
N227B R1-CCA03
- Physics (Quantitative Imaging and Radiomics)**
Joseph Lo, PhD, Michael F. McNitt-Gray, PhD
8:00am-9:00am
E350 R1-SSPH13
- Cutting Edge (Photon Counting CT)**
9:00am-9:30am
Learning Center Theater R1-STCE
- Deep Learning Lab: Accelerate your AI-based Medical Imaging Research MONAI Core on SageMaker**
Christopher C. Austin, MD,MSc, Steve Fu, Christoph Russ
9:00am-10:00am
Learning Center - DL DLL15
- Deep Learning in CT Image Formation**
Guang-Hong Chen, PhD, Marc Kachelriess, PhD, Lifeng Yu, PhD
9:30am-10:30am
E352 R3-CPH04
- Cutting Edge (Artificial Intelligence)**
10:30am-11:00am
Learning Center Theater R3-STCE
- Deep Learning Lab: Multimodal Fusion for Pulmonary Embolism Detection CTs and Patient EMR**
Mars Huang, PhD, Matthew P. Lungren, MD
10:30am-11:30am
Learning Center - DL DLL16

Thu, December 1

- Cutting Edge (Molecular Imaging)**
12:15pm-12:45pm
Learning Center Theater R5A-STCE
- Cutting Edge (Artificial Intelligence)**
12:45pm-1:15pm
Learning Center Theater R5B-STCE
- Cardiac Imaging (Advanced CT Applications)**
Gautham P. Reddy, MD, MPH, Lifeng Yu, PhD
1:30pm-2:30pm
N227B R6-SSCA11
- Cutting Edge (Photon Counting CT)**
1:30pm-2:00pm
Learning Center Theater R6-STCE
- Physics (AI in Medical Imaging)**
Samuel G. Armato, PhD, Andrew Missert, PHD
1:30pm-2:30pm
E353C R6-SSPH15
- Science Session with Keynote: Chest Imaging (Artificial Intelligence and**
Jin Mo Goo, MD, PhD, Anastasia Oikonomou, MD, PhD
1:30pm-2:30pm
N228 R6-SSCH10
- Chest MRI, PET-CT and Photon Counting CT Updates**
Lea Azour, MD, Christopher J-P. Francois, MD, Shuai Leng, PHD, Osama R. Maw...
3:00pm-4:00pm
N228 R7-CCH06
- Opportunistic Screening and Superhuman AI for Radiology**
Akshay Chaudhari, PhD, Kirti Magudia, MD, PhD, Hari Trivedi, MD
3:00pm-4:00pm
S401 R7-CIN25



Thu, December 1

Robust AI Solutions: Essential Image Acquisition Requirements

Michael Boss, PhD, Andrew J. Buckler, MS, PhD, Daniel C. Sullivan, MD,
Gudrun...

[3:00pm-4:00pm](#)

S406B

R7-RCP25