Grand challenges in artificial intelligence in clinical radiology and clinical oncology

A stakeholder event hosted by The Royal College of Radiologists in partnership with Health Data Research UK, The Alan Turing Institute and The Engineering and Physical Science Research Council

16 May 2018
The big challenge: harnessing artificial intelligence in healthcare

The noise surrounding artificial intelligence (AI) in healthcare is growing. Politicians and industry are increasingly heard extolling the potential of AI and machine learning to improve medical diagnoses via tireless data interpretation, as well as to improve the efficiency and financial situation of the NHS.

AI has clear applications in the medical specialties of clinical radiology and clinical oncology. Both disciplines depend on the assessment and cross-referencing of multiple data variables from medical images to diagnose conditions and plan cancer treatment.

Perceiving how integral AI will be to future healthcare advances in the UK, The Royal College of Radiologists (RCR) hosted a stakeholder event to debate the key issues surrounding its development and implementation, particularly with reference to the College’s two medical specialty areas of clinical radiology and clinical oncology.

The Grand challenges in artificial intelligence in clinical radiology and clinical oncology event took place at The Wellcome Collection in London on 16 May 2018.

The symposium was conceived by the RCR in partnership with The Alan Turing Institute, Health Data Research UK (HDR UK) and the Engineering and Physical Sciences Research Council.

The event was opened by Dr Nicola Strickland, President of The Royal College of Radiologists, who welcomed over 100 invited delegates – ranging from radiologists and clinical oncologists to computer scientists, industry experts and funding leaders – to a packed programme designed to explore the major challenges around training and regulation of innovative AI, and to introduce a selection of projects already being trialled in UK universities and hospitals. See Appendix 1 for a list of organisations that attended the symposium and Appendix 2 for the full programme.
Options and opportunities for health data science

The day’s first speaker was Professor Andrew Morris, Director of event partner, Health Data Research UK, the UK’s multi-funded central institute for advancing the use of healthcare data.

Professor Morris began by praising the timeliness of the event and repeatedly stressed the importance of clinical experts coming together for discussion and collaboration in order to realise the potential of AI and ensure digital technology impacts positively on healthcare.

He said AI is now starting to have a wide-ranging, immediate impact across industries, with a disruptive and exponential progression that is now beginning to touch on every area of society.

Professor Morris detailed HDR UK’s overarching purpose to harness big datasets to improve patient health. HDR UK currently oversees a network of 21 universities with shared terms of reference for data sharing, all working with NHS trusts and funders and by 2019 the institute hopes to have numerous multi-dimensional health data sets actively being mined to train AI, with associated governance and public engagement.

He concluded with an appeal to delegates to take charge of the direction of healthcare AI, saying that while the sector is now being positively flooded with capital, it is also an environment of ‘joint fear and optimism’ and that medics and AI producers must clearly demonstrate the clinical utility of developing products.
Keynote lecture: The grand challenges and opportunities in the application of AI in healthcare

Renowned surgeon Lord Ara Darzi gave the morning’s keynote address, calling on delegates urgently to collaborate to progress AI in clinical practice, both for the benefit of patients and to maintain the UK as a world leader in innovation after leaving the European Union (EU).

He described the progression of AI and machine learning advancing from descriptive to predictive insight eventually leading to making prescriptive recommendations for users (in a similar way to AI-generated shopping recommendations). In his talk he also highlighted how programmes are moving from supervised learning, with clinical oversight, through to unsupervised learning where AI technology can cluster at-risk patient groups. He then went on to highlight the massive potential for deep learning in radiology.

Compared to other industries such as finance, Lord Darzi showed the health sector has a middling spend on AI development, marking it out as a key area for growth an opportunity. However, he went on to stress a recurrent theme for the day, saying: ‘AI development will only be as good as the data we have’, later adding: ‘investing in data access and annotation will be the best innovation we could have’.

He reflected that machine learning in healthcare goes back to the 1970s, is not new and should be seen as a tool, rather than a replacement, for clinicians, adding that he sees a key area for AI being the prioritisation of imaging workloads, which is one of the biggest challenges facing hospital managers.

On data access, Lord Darzi called for urgent health sector leadership on the best way to utilise amassed NHS data, as well as the need for consistent annotation standards for NHS imaging studies to aid AI learning.

He concluded by saying that the integration of clinical expertise with technology firms and better data access are the key challenges in the field, and that if they are not addresses the UK will miss its opportunity to spearhead healthcare AI.

In the subsequent question and answer session with delegates he made a further appeal for this integration, especially with an economic outlook, saying that the UK’s post-Brexit survival could be dependent on demonstrating its economic clout in industries such as AI.
The grand challenges in clinical radiology and clinical oncology: clinical needs

The morning’s third presentation saw Dr Nicola Strickland return to the lectern to outline her hopes for the clinical applications of AI and to raise questions around the role of medical leaders, including the RCR, in hosting robustly curated databases for AI testing purposes.

Dr Strickland was confident of the prospect of healthcare AI working in tandem with clinicians for the benefit of patients, and appealed for radiologists and oncologists to work with AI firms and engage with clinical researchers to bring the technology forward into practice as soon as possible.

She outlined the ongoing workforce crisis in radiology, with clinical demand annually outstripping the growth in radiologist numbers – and as a result, said AI should be trained to order radiologists’ reporting worklists, by detecting and deprioritising normal imaging studies so that serious pathology could be prioritised to the top of the reporting worklists.

Like previous speakers, she also emphasised the need for huge repositories of data for training, validating and testing AI algorithms, as well as expert annotation standards.

Dr Strickland said her own hopes for AI were to see it prioritising high demand imaging studies, such as determining fractures on X-rays to speed up triage, as well as using AI to determine childhood bone age, or the position of nasogastric tube tips. Another key area could be using AI in the urgent interpretation of computerised tomography (CT) head scans for suspected stroke patients, where life-changing mechanical thrombectomy treatment is time-sensitive.

Another key area for Dr Strickland was ‘radiomics’ – in which multiple vectors contained within imaging data are analysed, and combined with genomics and other clinical information, to give personalised diagnosis and prognosis for patients. While she admitted radiomics would be another 10-20 years in development, she believes it ‘has the potential for real personalised medicine thanks to data extraction by AI’. She said a concurrent challenge would be the widespread integration of AI programmes into existing hospital IT systems.

She concluded her talk by asking delegates to consider whether the RCR, and fellow medical leaders such as The Royal College of Pathologists, should have a role in securing a national training database, as well as directing the regulation of clinical AI.

Asked in the following question and answer session if she believed radiologists were ‘taking their hands off the wheel’ by embracing AI, she replied that clinicians must make use of technological developments to free up capacity, especially as staff shortages already mean some best practice guidelines are unable to be realised due to lack of staff. She stressed that radiologists will be working with AI, to improve the quality of their work, and will never be replaced by AI.
Hot topics in AI research and real world examples of using AI to improve clinical outcomes

The event’s late morning presentations comprised of a series of quick-fire presentations by clinical researchers involved in AI work, in which they reported on ongoing studies and discussed the sector’s developmental needs to ensure AI can be used in practice to improve patient outcomes.

Consultant radiologist Professor Fergus Gleeson, of Oxford University Hospitals, talked delegates through the challenge of teaching AI to recognise if lung nodules are benign or malignant. He introduced the Optellum project, an ongoing Oxford-based collaboration of machine learning and imaging experts working to train deep learning software to spot lung cancer nodules on CT images, so far with nearly 100% accuracy.

Professor Gleeson also appealed for improved data access for researchers to enable AI to learn from different population variables, with his hope being the development of universal population screening for lung cancer.

Imperial College London-based radiologist Professor Andrea Rockall discussed the increased complexity of using highly sensitive whole-body magnetic resonance imaging (WB-MRI) to help with cancer staging, and introduced her centre’s Machine learning in body oncology study which, though small-scale, has been successful in teaching AI to detect and fully automatically segment lesions from whole-body MRI scans.

Radiologist Dr Declan O’Regan, also from Imperial College London, introduced his ongoing work successfully training AI to model individual heart function based on MRI. The computerised models of a patient’s heart function are then able to be combined with long-term prognosis data to determine that individual’s risk of pulmonary hypertension and, in turn, tailor treatment.

The next speaker, Imperial-based clinical oncologist Dr Matt Williams, gave a provocative talk exploring the use and ownership of big datasets, which are so fundamental to the robust training of AI. He argued patients should always have access to their medical data and the power to curate it; however, the prevalent assumption that patients own their data is both wrong and impeding data access.

Dr Williams discussed the three-way data sharing gridlock as an example of the ‘Tragedy of the anti-commons’ and suggested the development of agile, revocable data sharing contracts between hospitals, technology developers and patients to allow better access to much-needed training data for AI, while preserving patient control and involvement.
Oxford-based machine learning expert and Fellow of The Alan Turing Institute, Professor Mihaela van der Schaar, presented an update on machine learning in breast screening, on behalf of leading breast radiologist Professor Fiona Gilbert. Professor van der Schaar talked delegates through Professor Gilbert’s work on the Auto-prognosis programme – as well as its precursor Autoscreen – which fuses 100 different machine learning programmes to identify risk factors and the best breast imaging techniques for women undergoing breast cancer screening.

Professor Daniel Rueckert, Head of Computing at Imperial College London, stressed how ‘disruptive’ AI could be used to speed up data acquisition from diagnostic imaging, with less reliance on human clinicians, as programmes can glean measurements and other metrics from sub-sample data without needing a fully composed scan image. Examples included ongoing work using AI to collect data from cardiac MRI and brain trauma CT scans, as well as making automatic measurements in fetal ultrasound imaging to assess fetal health and growth.

Computational imaging expert Professor Julia Schnabel, of King’s College London, outlined the existing issues around data availability facing UK researchers, which has so far resulted in the field only being able to use comparatively small-scale, dedicated trials for AI development. She emphasised that that these data are, however, very dense and rich in nature, often with a multi-modal or temporal component. Echoing her co-speakers, she reiterated the need for larger amounts of training data and expert annotations to develop AI that would be fit for widespread clinical use.

Image analysis expert, Dr Sue Astley, from Manchester University, detailed the challenges facing her team attempting to develop a sophisticated AI screening tool to predict breast cancer in patients by quantifying and characterising high-density breast tissue which, if developed further, has the potential to be able to identify high-risk patients for early intervention and additional screening.

Neuroradiologist Professor Adam Waldman, from the University of Edinburgh, sees the main clinical application of AI as being around decision support, particularly combining quantitative and multi-modal data for comprehensive diagnosis. He also raised the potential for AI to be used to streamline image data acquisition and optimise display of diagnostic images. He explained that his own research team use AI for image segmentation and progress the field of radionics and radiogenomics.
Infrastructure and research opportunities for the UK

The afternoon sessions began with talks about data networking, with a key focus on ways to increase academic and industry access to NHS imaging studies.

RCR Informatics Committee Chair and Doncaster-based radiologist Dr Neelam Dugar urged all UK radiologists to get involved in helping to amass the data that are needed for AI training. However, this would require national level investment in connecting all clinical picture archiving and communication systems (PACS) to a national research image archive of de-identified images. Addressing the issue of image data de-identification at the source PACS will be key to success. Radiologists would also need to be motivated to submit cases with protected time to do so.

Her colleague on the College’s Informatics Committee, Dr Hugh Harvey, outlined his vision of a national NHS-fed imaging database, nicknamed the British Radiology AI Network (BRAIN), which would host anonymised patient images to be accessed by AI developers.

Like speakers before him, Dr Harvey admitted the challenge would be the universal standardisation of image type and annotation across hospital PACS that would need to be overcome to produce a useful national data pool. Calling for a more streamlined approach to AI research across the UK, he urged research delegates and technology firms to collaborate, instead of continued scattered silo working.

Giving a data scientist perspective of AI in pathology, Professor Nasir Najpoot from the University of Warwick argued that pathology images contained a wealth of potentially useful information, and emphasised the role of AI in pathology for bridging the gap between genomics and radiology on the spectrum of various length-scales in oncology. He gave examples of recent research from his tissue image analytics (TIA) lab at Warwick. In particular, he spoke about the ongoing MILD-Net project which is a novel AI-based model to accurately segment glandular structures in colon histology images. He also spoke about PathoSource, a crowdsourcing platform for annotation in pathology images.

Putting good quality annotations together with the AI-based algorithms will mean AI can profile the particular micro-environment of tumours from pathology slides, the results of which can then be used to extract valuable insights for predicting survival and progression of cancer and determining specific treatment.

Oxford University-based imaging neuroscience expert Professor Clare Mackay talked to delegates about the developing Dementias Platform UK project, which pools dementia data from research institutions in a federation model to enable researchers to share data. She explained the problem with existing trial data is that the data are generated from patients with advanced conditions, so the dementia research community is hoping AI can be used in future to look at chemical and biomarker changes to identify high-risk patients earlier.

Following these presentations, the panel question and answer discussion focused on how a centralised data training set for AI could work in practice, with particular concern around the anonymisation of patient data. Dr Harvey said images coming into his envisaged BRAIN imaging database would be cleaned of identifiable data, while Professor Rockall, speaking from the audience, stressed such a system would need a series of robust checks and balances to maintain data integrity and good quality annotation.
The value of industry research in AI imaging

The final presentations round of the day featured three industry talks in which speakers outlined a number of their current AI projects and made calls to action to strengthen progress in the sector.

Microsoft Research’s Antonio Criminisi teamed up with clinical oncologist Dr Rajesh Jena to introduce Microsoft’s image segmentation solution for clinical oncologists. They demonstrated the cloud-based technology by showing how it can be used to speed up the preparation of radiotherapy treatment plans. The Innereye team at Microsoft Research are partnering with Cambridge University Hospitals to evaluate this technology.

Dr Jena explained that patients opt-in to having AI techniques applied to their radiotherapy treatment plans and that the outlining returned by the programme is cross-checked by clinical oncologists. This also helps with the continuous improvement of the AI algorithms. Asked about regulation of the programme, Mr Criminisi said that each new iteration of the programme has an identification number, to facilitate audit and compliance tracking by users of the system and by Microsoft’s researchers.

Kheiron Medical Technologies’ CEO Dr Peter Kecskemethy explained his company has been fine-tuning their machine learning software for breast cancer screening, which is now awaiting regulatory approval in Europe.

His talk focused around the realities of AI development, and stressed that the biggest challenge to developers would be demonstrating the robust testing of programmes in order to scale their application and have them trusted in clinical practice. Dr Kecskemethy urged AI industry delegates to work with clinicians to carefully engineer their products and to be honest about the limitations of their technology.

Dr Alison O’Neil, from Canon Medical Research Europe, talked about Canon’s development and its AI objectives, adding that it has now created its own AI innovation hub which it is preparing to mobilise to bid for funding to help create AI training datasets. Dr O’Neil introduced a range of Canon-funded AI currently being tested in the UK, including using frailty measurements to model interventions for elderly patients in Nottingham, a Glasgow trial using AI to predict mesothelioma and a system being developed to detect urgent signs of stroke from CT scans.
Innovate UK announcement regarding summer funding round for imaging AI

A key delegate on the day was Dr Penny Wilson, lead for stratified medicine at the Government’s innovation agency Innovate UK. Following the industry-led presentations, Dr Wilson was invited on stage to announce Innovate UK’s next bidding window, which runs from June–August 2018 and is particularly focused on the creation of collaborative research hubs for diagnostics and imaging AI.

Dr Wilson appealed for interested bidders and outlined a vision of AI development hubs to act as centres of collaboration between clinicians, industry, regulators and health economists. To find out more about the bid round visit: https://apply-for-innovation-funding.service.gov.uk/competition/177/overview

Breakout sessions – challenging the ethical and practical development of diagnostics AI

The symposium’s finale comprised three planned breakout sessions, with delegates asked to attend any two sessions of interest and contribute their opinions. The sessions focused around creating a collaborative, practical environment for AI development in the UK, the need for regulation and the role of the RCR and other medical professional bodies in progressing healthcare AI.

Creating outstanding research resources

In this session, chaired by Professor Chris Holmes of Programme Director for Health at The Alan Turing Institute, the primary concern for delegates was enabling AI researchers and industry to have access to validated, well-curated datasets. However, they agreed incentives would be needed, as currently data set creation does not attract funding. Delegates queried if Scotland’s national PACS would be open to researchers, as well as suggesting the RCR was well-placed to link data from trusts to provide a centralised data pool, similar to the American College of Radiology (ACR) model in the USA.

The audience noted it would be helpful to establish guidelines and standards for machine learning research methodology and that the RCR, again, would be in a good position to take on this role.

Funding acquisition and public ‘buy-in’ was important to delegates, who warmly welcomed Dr Wilson’s announcement of Innovate UK’s ongoing call for bids. It was felt there needed to be greater clarity and honesty about the potential and limits of AI for supporting clinicians, and the areas that should be prioritised. Widespread public ignorance and concern about AI was also noted, and delegates argued more could, and should, be done to promote understanding and support for AI applications in medicine.

Encouraging researchers and industry to collaborate was deemed key to the future success of healthcare AI, and it was suggested that the RCR could play a further role identifying key challenges for academia and industry to explore. It was agreed that having a safe ‘sand pit’ area in which researchers and developers could experiment was a good way to encourage further participation in the field.
Perspectives on ethics and the regulatory environment

This session, chaired by Professor Andrew Morris, highlighted the developmental state of the healthcare AI sector, as delegates found themselves raising more questions than answers around accountability and regulation.

Many delegates were not convinced that existing models of approval are tight enough for clinical culpability to be adequately addressed, questioning whether the AI producer or the clinician using emergent AI software, has ultimate medical liability. It was noted that AI already in use, such as guided radiotherapy software, is more accurate than human clinicians but that the clinician remains responsible. Delegates agreed that the concept of ‘computer assisted doctors’ was far from new – with the onus remaining on the clinician using the computerised tool – and that AI should be considered an evolutionary change, as opposed to a revolution.

Concerns around AI regulation were countered by some delegates who asserted they would be covered by existing ethical and regulatory frameworks in research. Fears around accountability were linked to the fast-evolving nature of AI, which delegates suggested could be mitigated by adaptive product licensing. Crucially, it was noted that officials have recognised these concerns, with the Government’s formation of an AI Council, the Centre for Data Ethics and Innovation and the Office for AI. However, questions were raised regarding how these bodies will interact with existing agencies such as the Medicines and Healthcare products Regulatory Authority and NHS Digital.

Public perception and expectation of sharing health data, often fuelled by sensationalist media, was repeatedly cited by delegates as a barrier to AI adoption, with many arguing concepts of data ownership are frustrating AI development. It was noted that research into patient perceptions often shows trust in healthcare but not in the industry behind it.

Delegates concurred that the social contract with the public is crucial, while noting that centralised data can incite public fear and mistrust, citing the example of NHS England’s failed Care.data project. Questions were also raised as to whether the new General Data Protection Regulations would impact on the sharing of anonymised data.
Making AI a friend not an enemy

Chaired by RCR President Dr Strickland, this session asked delegates to explore the role of professional organisations such as the RCR in developing and policing AI, as well as asking questions around AI testing and accountability.

Debate initially centred on the challenges of accessing large-scale, well-annotated data, with queries as to whether Wales and Scotland’s developing national PACS could be utilised. Researchers argued that a large national dataset that reflected population variables would be immensely valuable for training AI and questioned whether the RCR could host and fund a centralised database along the lines of the ACR model in the USA.

However, other industry and research-based audience members countered that training datasets should be smaller, refined and iterative to give AI the most useful data from which to learn. It was also questioned who would be prepared to build such a large but bespoke database and whether focusing on greater collaboration between existing data sharing hubs would be more beneficial and expedient.

Another suggestion was for the piecemeal establishment of a national pooled database, potentially curated by the RCR, from which industry could request specific tailored data from. Others argued that smaller-scale, protected collaboration agreements with hospitals and other data suppliers would be more realistic and attractive to industry.

The regulation of AI products and data testing standards was also heavily discussed, with most delegates keen for the RCR to play a leading role in standard-setting for relevant AI in radiology and clinical oncology. The ongoing Government establishment of the Centre for Data Ethics and Innovation was also raised, and delegates argued it was essential the RCR took a role in ‘data trusting’ and ensuring the regulation and safety of relevant AI.

Questions around the standardisation of AI brought the discussion back full-circle to planning the usage of datasets and the importance of understanding the degree of annotation and metadata needed for AI programmes of varying complexity.

Closing remarks

Closing the programme, Dr Strickland issued a heartfelt thanks to the assembled partners, speakers and delegates for their attendance and thought-provoking contributions throughout the day.

She concluded by saying the event hopefully marked ‘just the beginning’ of future collaboration between stakeholders and urged all delegates to take up the mantle and become involved in shaping the future of medical AI.
Appendix 1. Organisations represented by delegates at the meeting

4ways Healthcare Ltd
Academy of Medical Royal Colleges
Agfa HealthCare
AI-Precision Radiology Initiative, AIMES
Aptus Health
Basildon University Hospital
Cambridge University Hospitals
Cancer Research UK
Canon Medical Research Europe
Cantab Capital Institute for Mathematics of Information
Care Quality Commission
Cerner
Engineering and Physical Sciences Research Council
Everlight Radiology
Frimley Health
FUJIFILM UK Limited
Future Advocacy
GE Healthcare
Guy’s and St Thomas’ Hospitals
Health Data Research UK
Health Data Research UK Midlands
Health Education England
HM Naval Base Portsmouth
IBM Watson Health
Imperial College London
Institute of Digital Healthcare
Kheiron Medical Technologies
King’s Technology Evaluation Centre (KiTEC)
King’s College London
Leeds University
Liverpool Heart and Chest Hospital
Medica Group
Microsoft Research
Mount Vernon Hospital
Musgrove Park Hospital
National Cancer Research Institute
National Hospital for Neurology and Neurosurgery
National Institute for Health Research
NHS England
NHS Improvement
Optelium Ltd
Oxford Big Data Institute, University of Oxford
Oxford Internet Institute, University of Oxford
Oxford University
Oxford University Hospitals
Plymouth Hospitals NHS trust
Pontefract General Infirmary
Professional Record Standards Body
Queen Mary University of London/Barts Health
Royal College of Emergency Medicine
Royal College of Pathologists
Royal College of General Practitioners
Royal College of Surgeons in Ireland
Royal College of Surgeons of England
Royal Cornwall Hospitals NHS Trust
Royal Free London NHS Foundation Trust
Royal Wolverhampton NHS trust
Siemens Healthcare Ltd
Singapore Radiological Society
Society and College of Radiographers
Swansea University
The Alan Turing Institute
The Engineering and Physical Sciences Research Council
The Institute of Cancer Research and The Royal Marsden Hospital, London
The Institute of Global Health Innovation, Imperial College London
The Royal College of Radiologists
The Topol Review
UCLH Biomedical Research Centre
UKRI Innovate UK
University College London
University Hospitals Birmingham
NHS Foundation Trust
University of Aberdeen
University of Birmingham
University of Bristol
University of Cambridge
University of Edinburgh
University of Leeds
University of Leicester
University of Lincoln
University of Liverpool
University of London
University of Manchester
University of Strathclyde
University of Toronto
University of Warwick
Usher Institute of Population Health Sciences and Informatics
Velindre Cancer Centre
Wellcome Trust
William Harvey Research Institute
Appendix 2. Programme

10:00–10:05 Welcome
Dr Nicola Strickland, President, The Royal College of Radiologists

10:05–10:10 Options and opportunities for health data science
Professor Andrew Morris, Director, Health Data Research UK

10:10–10:35 Keynote lecture: The grand challenges and opportunities in the application of AI in healthcare
Speaker: Lord Ara Darzi, Director, The Institute of Global Health Innovation, Imperial College London

10:35–10:50 Potential benefits of AI in clinical radiology and clinical oncology
Chair: Dr Nicola Strickland, President, The Royal College of Radiologists

10:50–11:40 Hot topics in AI research
Chair: Professor Andrew Morris

11:40–12:20 Research to clinic: real world examples of using AI in research to support improvements in clinical outcomes
Chair: Dr Nicola Strickland

13:20 –14:20 Infrastructure and research opportunities for the UK
Chair: Professor Andrew Morris

16:25–17:10 Breakout sessions

Workshop 1: Creating outstanding research resources
Moderated by: Dr Chris Holmes

Workshop 2: Perspectives on ethics and the regulatory environment
Moderated by: Professor Andrew Morris

Workshop 3: Making AI a friend not an enemy
Moderated by: Dr Nicola Strickland

17:10–17:30 Plenary – review outputs of each workshop

17:30 Closing remarks: Where we go next
Dr Nicola Strickland and Professor Andrew Morris